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OUR FOREST RESERVATIONS.

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IT is highly probable that the future will chronicle the act of March 3, 1891, under which the Chief Executive of the United States is given power to segregate forest reservations from the public domain, as a law most fruitful in results of vast import to the future welfare of the country. Armed with the power conferred by this act, the successive Presidents have in the past ten years established no less than thirty-nine national forest reservations.

As the act provides that the reservations are to be segregated from the public domain, they are for the most part in the Rocky Mountain region and in the Pacific Coast States where large areas of public forest lands were available.

The thirty-nine reservations in the aggregate contain more than 46,800,000 acres, an area more than fifteen times as large as the State of Connecticut, or about one-fortieth of the total area of the country exclusive of Alaska.

Much controversy has arisen as to the wisdom of withdrawing such large areas of the public lands from sale or from other disposition under the laws of the land office. Much of the opposition has disappeared during the past few years, and public sentiment in favor of forest reservations is rapidly increasing. In fact, so rapid has been this change in public sentiment that a movement is now on foot, with prospect of success, to establish a national forest reservation in the southern Appalachian Mountains, where it will be necessary for the Government to purchase the land at an expense of several million dollars. There is also an effort being made on the part of a good many public-

spirited citizens to establish a national reservation in Minnesota, at the head of the Mississippi River. Unfortunately, however, the latter effort is at present checked by the lumber interests of the region, although these interests would profit in the long run by the establishment of the reservation.

Forest reservations are not entirely national affairs. Stae reservations are already an established fact in a few States and the indications are that they will be formed in many others during the next decade. The State forests in the Adirondack Mountains in the State of New York are splendid examples of such reservations. These lands were purchased at State expense that they might remain forever in forest, a great heritage for both pleasure and profit for all time.

Similar reservations have been established during the past few years in Pennsylvania, and others are likely to be set aside in Michigan before the close of the present year.

Going hand in hand with the making of the State and National reservations, there has been a rapid development in public sentiment as to the importance of practical forestry and its application to the management of the wooded areas of the country, both public and private.

This change in public sentiment is well illustrated in the volume and character of the investigations in forestry by the Government, when compared with what they were a few years ago. In the Division of Forestry of the Department of Agriculture alone, the appropriations have increased more than six-fold in three years, thus making it possible to extend the study of important problems in American forestry to many of the varied sections of the country. It is well illustrated in the rapidly increasing facilities for instruction in technical forestry in our recently established forest schools and the courses in forestry offered in many of our colleges and universities. It is shown in the fact that owners of private woodlands are in some instances employing trained foresters to superintend their lumbering operations, so that their methods of cutting will not interfere with the perpetuation of the forest. It is shown in the yearly increasing appropriations for forestry investigations by the legislatures of the several States, but most of all it is shown in the rapidly increasing number of applications coming to the trained foresters of the Government from the owners of private woodlands for assistance and advice in the management of their forests and in establishing plantations of forest trees.

I desire to make clear that this changing sentiment regarding our forests is most fortunate for our future welfare. American prosperity has been largely due to the productiveness of American soil, *i. e.*, to her agricultural and forest products, the value of the latter approximating $1,000,000,000 per year at the present time. The effect

upon the soil of these two classes of products is very different. Agricultural crops being removed when mature, practically in their entirety, impoverish the soil, while forest crops, being removed only in part and then at long intervals of time, have an opposite effect, as they for the most part enrich the soil.

For many reasons it is highly important that even in agricultural regions a varying proportion of the land should remain in forest, not only for the direct value of the products which it affords and its value in enriching the soil, but for its beneficial influence upon the adjacent cultivated fields which it is not necessary for me to recount here.

THE FOREST RESERVATIONS ARE STILL THE HAUNTS OF THE RAREST AND LARGEST GAME THAT THE COUNTRY AFFORDS. STANISLAUS RESERVATION, CALIFORNIA.

If it be desirable that a certain proportion of our agricultural lands be kept as woodland, it is important that they be made to produce desirable products in the largest degree consistent with economy. This can only be brought about by a rational system of management, where skill and foresight is exercised to as great a degree as in the successful production of agricultural crops.

Although much might be said regarding the importance of well-managed woodland in agricultural regions, it is to the vast area of non-agricultural land in this country that the application of practical forestry will be of incalculable value. It is highly important that our non-agricultural lands be made to contribute toward our national

wealth. There is no other contribution which they are capable of making that will compare, both directly and indirectly, with their forest growth.

Experience has abundantly shown that the natural selfishness of man leads him to excesses in the utilization of forest products. His tendency is not only to consume a product equal to the growth of his own time, but to make large inroads upon the future. He is profligate in the use of wood, often leaving all but the very best to decay upon the ground or to become fuel for forest fires.

The justification for our forest reservations should not, however, be based entirely upon their value in conserving timber. They have,

EXCESSIVE, UNRESTRICTED AND INDISCRIMINATE GRAZING HAS INVARIABLY LED TO THE DESTRUCTION OF THE YOUNG GROWTH ON THE FOREST FLOOR. BLACK MESA RESERVATION, ARIZONA.

for the most part, been wisely selected to fulfil a threefold function, viz.: that of protection and luxury, as well as that represented in the direct value of forest products. Indeed, at the present time their direct value is in many instances of minor importance. On the other hand, as the reserved lands are almost entirely mountainous in character and located at the headwaters of many of our important streams, their value as conservators of moisture is very great, and it is to their maintenance in many instances that the farmers and ranchmen in the adjacent valleys must look for a perennial supply of water for their crops and stock.

In the selection of the reservations, consideration has also been given to their value from the standpoint of recreation and sport.

They contain a large part of the wildest, grandest and most picturesque portions of the American continent, and many of them are still the haunts of the rarest and largest game that the country affords.

The segregation of the forest reservations from the public lands, without the establishment and execution of regulations for their protection and management, would have but little effect in itself upon the preservation of their forests as shown in the present condition of the forests on our unreserved lands. Excessive, unrestricted and indiscriminate grazing has invariably led to the destruction of the young growth on the floor of the forest.

Where such grazing is continued for a number of years, the forest

YOUNG PINE SEEDLINGS—THE FUTURE FOREST—WHERE UNINJURED BY FIRE AND GRAZING. OLYMPIC RESERVATION, WASHINGTON.

rapidly deteriorates, for there are not a sufficient number of young trees to form a proper leaf canopy when the old ones are removed or when they mature and decay. We appear to lack a realizing sense that it is the young growth and not the old trees that insure the perpetuation of the forest.

As the reservations could not be treated in similar manner as the unreserved lands, with any expectation of preserving or improving the forest growth, provision was made by the U. S. Land Office, which was responsible for the management of the reservations, for the appointment of certain forest officials, viz.: superintendents, supervisors and forest rangers, these officers having immediate control of the reserved lands as to management and protection. Largely from their lack of both

THE COVER OF THE SOUTHWESTERN RESERVATION IS MOSTLY CHAPARRAL, EITHER MIXED WITH A SCATTERED GROWTH OF SINGLE TREES OR WHOLLY OF SHRUBBY PLANTS. SAN JACINTO RESERVATION, CALIFORNIA.

THE ALTITUDE IS OFTEN TOO GREAT FOR THE GROWTH OF DESIRABLE TIMBER. SIERRA RESERVATION, CALIFORNIA.

a practical and technical knowledge of forestry, and, in most cases, even of woodcraft, their work has been necessarily limited. From lack of training and experience they have been unable to create and put into execution a practical system of forest management for the lands under their control. Although unable to cope with the problems of management, they have been able in many instances to afford the reservations a fair degree of protection from fire and grazing.

As the forests of the reservations must eventually be utilized for their timber and other forest products, in order to make direct contributions to the national wealth, the work of management must go beyond that of simply protecting them from fire and grazing, even if this were afforded to the fullest degree possible.

They should be so managed that wherever the mature timber has material value it can be harvested and sold. The utilization of the forest products, however, must not interfere with the perpetuation of the forest. The cutting must be so conducted that the forest be maintained in the best possible condition as to reproduction and growth consistent with economy. In order to do this it is necessary that the reservations be under the control of practical and trained foresters.

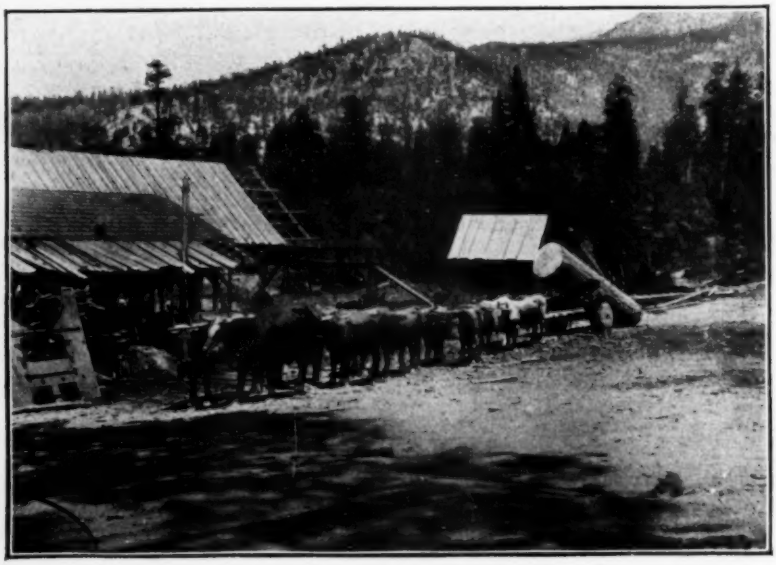
It is extremely gratifying to know that within the past few months the direct management of the national reservations, so far as it relates to questions of practical and economic forestry, has been transferred to the Division of Forestry of the Department of Agriculture, where they will receive attention from trained foresters. Working plans will be made for all the reservations, and the prospects are extremely flattering that on these 46,800,000 acres of reserved forest lands there will develop a system of American forestry that will have far-reaching influence on our future prosperity.

At first thought it may appear that it is not necessary to make forest reservations for the purpose of conserving the timber and lesser forest products in a country so splendidly wooded as the United States. When we consider, however, that, from the most reliable sources of information that we have, the amount of timber consumed exceeds the amount normally produced by the forests, we must know that the excess of consumption is at the expense of the main wood capital. In many instances this decrease is not so much on account of decrease in area as on account of decrease in productive capacity of the forests themselves.

Having such a splendid and large original supply to draw upon, we consume much more wood per capita than any other nation. At our present rate of consumption the most reliable authority that we have places the present supply as sufficient for our requirements for about fifty years, without taking into consideration the annual increment of the forests during this period.

It is difficult for us to comprehend our present yearly consumption of wood in all its varied uses. Conservative and accepted authorities place the present yearly lumber cut in this country at 40,000,000,000 feet (B. M.), while this is estimated to be but one-seventh of the total wood consumption. If it were possible to cut the entire amount yearly consumed into boards an inch thick, they would cover a walk six feet wide that would extend more than 354 times around the earth at its greatest diameter.

Although the amount of wood produced each year by the growth of the forests of the entire country is very great, it is a long way from what it might be both in quantity and quality were our forests ade-



TIMBER GROWS BUT TO BE UTILIZED. LUMBERING ON PRIVATE HOLDINGS WITHIN THE BOUNDARIES OF THE SAN JACINTO RESERVATION, CALIFORNIA.

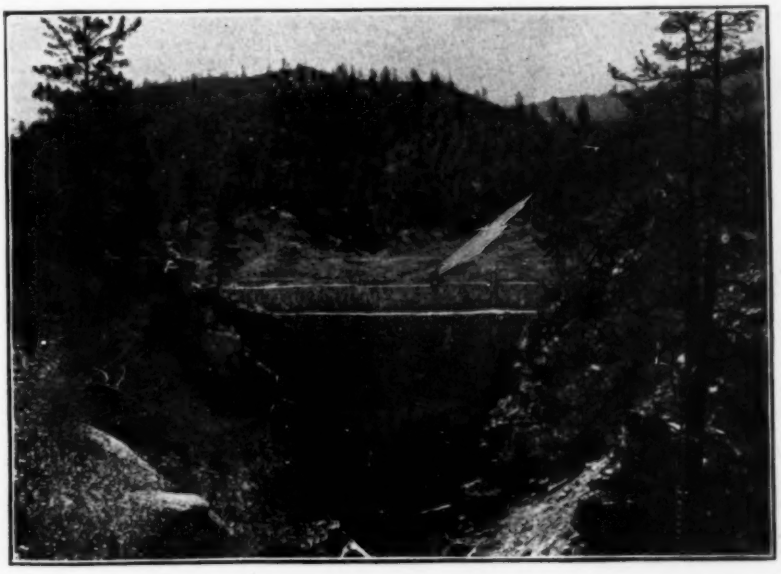
quately protected and managed. It will certainly not be sufficient to supply our requirements, after the virgin timber is exhausted, without the organization of a system of management which will keep the lands assigned to forest growth properly protected and in a desirable condition as to reproduction and growth.

This is well illustrated in the present unsatisfactory condition of much of the woodland in the Eastern States that has been cut over at various times without consideration for a future crop and left without protection and to chance reproduction. In the oldest part of the Union, viz.: the original thirteen States, the latest report, based upon trustworthy figures, places the wooded area at a little over fifty-five per cent., yet without systematic forest management, how

utterly inadequate this comparatively large area is to provide those States with their present wood requirements, more particularly timber of desirable dimensions for first-class lumber.

As one would naturally expect from the great variations in climate and topography, there are marked differences in the reservations in the quality and quantity of timber per acre. Indeed, such reservations as the San Jacinto and San Gabriel in Southern California, reserved primarily for the protection which they afford the adjacent cultivated lands, bear merchantable timber, but on a small percentage of their total area.

The large part of the vegetation is brush or chaparral, either mixed



THE HEMIT RESERVOIR, SAN JACINTO RESERVATION, CALIFORNIA.

with a scattered stand of single trees or wholly composed of shrubby plants. It should hardly be dignified by the term forest.

From these Southwestern reservations of the arid and semi-arid regions, with little timber of commercial importance, to the rich stands of splendid timber, covering large areas of the Washington and Mount Ranier reservations in the State of Washington, our thirty-nine reservations show all variations in the density of their forests. On the whole, however, but few of them have a large percentage of their total area covered with first-class commercial trees. In some instances the altitude is too great for the growth of desirable timber, while in others the lack of moisture will not permit its growth at low elevations. It is in the intermediate zones that tree growth is at its best.

Although a large number of species make up the forests of the reservations, they are for the most part composed of pines and other conifers, with the yellow pine and red fir a long way in the lead in commercial importance. The former of these two species is found in every one of the thirty-nine reservations, with the exception of the Apognak Reservation, in Alaska, and in many of them forms the major part of the forest, while the latter has nearly as wide a distribution.

In the Washington reservation pure stands of red fir may be classed among the finest forests in the world. Not infrequently single trees reach a height of from 250 to 300 feet, and contain 25,000 feet (B.M.) of merchantable lumber. The trees stand close together, their long, straight boles shooting upward like so many shafts from the dimly-lighted bed of moss and ferns forming the floor of the forest. This

OUR RESERVATIONS MUST BE PROTECTED FROM FIRE, SO FAR AS AN EFFICIENT FOREST SERVICE CAN PROTECT THEM. OLYMPIC RESERVATION, WASHINGTON.

same tree, of a more stunted and shorter growth, forms a considerable part of the forests of the more southern reservations, even growing in the forests of Arizona. Here, however, the forest is open and the drooping limbs cover the boles nearly to the ground, rendering them of little value for commercial purposes, but of vast importance in shading the ground and thus aiding in the conservation of moisture.

No greater mistake can be made than to consider the timber supply of the reservations as confined to the mature trees that we find growing there at the present time. We should look into the future and ask what are these 46,800,000 acres of reserved lands capable of producing as an annual increment when properly protected and managed. What kind of forests are they capable of producing in the future, long after the trees now living shall have been harvested or have gone to decay?

The value of this vast inheritance, which is placed in our keeping for future generations, will depend upon how well we manage it. By this is not meant how well we protect the mature trees from the woodman's axe, but how well we protect the tender seedlings, that are to form the future forest, from being destroyed from outside influences.

Timber is grown but to be utilized, hence it is the duty of those having the reservations in charge to see that it is utilized at the proper time wherever accessible and of sufficient value to pay for the cutting.

FORESTS OF SAME REGION AS SHOWN IN PREVIOUS ILLUSTRATION WHERE UNINJURED BY FIRE. OLYMPIC RESERVATION, WASHINGTON.

It is far more important, however, at the present time, to preserve and improve every factor that leads toward the perpetuation of the forest and in keeping it at its best in reproduction and growth.

It is worth while to consider briefly the indirect value of the forest reservations from the standpoint of water conservation. Although this is a factor to be taken into account in considering the value to the nation of each of the reservations, nowhere is it more apparent than in Arizona and Southern California, where the scarcity of water and its utilization for purposes of irrigation give it enormous value. It is to

THE CONDUCTING OF LOGGING OPERATIONS ON PRIVATE LANDS WITHIN THE RESERVATIONS CAUSES MANY FIRES, SOME OF WHICH ESCAPE TO THE RESERVED LANDS. SAN BERNARDINO RESERVATION, CALIFORNIA.

WHERE THE STREAMS ABOUND IN TROUT. SAN BERNARDINO RESERVATION, CALIFORNIA.

a large measure the reservations of these regions and the preservation of their forest cover that give such great value to the adjacent cultivated fields. It is the water and not the land that has value. It is the perennial supply, flowing from the reserved and unreserved forests of East and Central Arizona, that has in the past two decades rescued the Salt River Valley from its former barrenness, with its scattered growth of creosote brush and cacti, and transformed it into one of the most fertile and productive areas in America. It is the forest cover of the San Jacinto and San Barnardino reservations in Southern California that gave Riverside and Redlands her splendid orange groves and made possible the development of a productive and thriving community.

When in our Western forests one is constantly impressed by the change in relative humidity wrought wherever the forest has been removed. Springs have disappeared and cañons and ravines are now dry, where there were formerly perennial streams. Under the leaf mold and other débris of the forest, the soil is always moist, while on denuded areas in the same locality it is parched and dry. Everywhere the deep mulch forming the floor of the forest grasps the descending rains and melting snows and guides them into the deeper recesses of the earth. Where the forests have been destroyed, or even the mulch and litter forming the forest floor, as it so often is by fire or the excessive grazing of sheep, the rains for the most part, instead of sinking into the soil, pass over the surface, carrying silt and other débris into the streams and reservoirs, causing vital injury to irrigation enterprises.

So also in the semi-arid regions, where there are no forests, or where they have been destroyed, the wind has a free sweep, resulting in an enormous increase in evaporation. In some instances the evaporation from a water surface exposed to the free sweep of the wind reaches a maximum of thirteen inches in a single month. In exposed situations, snows a foot in depth are frequently lapped up in a single day without even moistening the soil beneath. We do not appreciate how great the necessity for the preservation of the forests is to the irrigable West.

Reservoirs for the purpose of impounding water to be used in irrigation have been constructed by private enterprise in many parts of the West, and the possibility of governmental construction of such reservoirs is by no means improbable. Effective reservoirs are not possible in our irrigable regions without due regard for the forests that feed the streams which fill them. Forests everywhere are the great preventors of erosion, and nowhere is this more evident than in our Western mountains. The utility of reservoirs, and, to a lesser extent, of distributing canals and laterals, becomes destroyed as they fill with

silt. To prevent this filling, the forests must be preserved; they must be protected from fire, in so far as an efficient forest service can protect them, and also from grazing, wherever it seriously interferes with the effectiveness of the forest floor as a water absorbent. In some of the Southwestern reservations, notably in Arizona, sheep-grazing has been carried so far that natural reproduction is at a standstill, and the forest floor has been made in some places almost as bare and compact as a road-bed. It is reasonable to expect that overgrazing will continue, until every hoof that enters the reservations is there under a permit based upon the judgment of a competent forester, who shall have absolute decision as to the portions of the forests that can be safely grazed and those that cannot.

One of the most fertile causes of injury to the forest cover of the reservations arises from the numerous private holdings of non-agricultural lands within their boundaries. From personal experience I know that the harvesting of the timber on these small areas of private lands in the San Bernardino reservation and the leasing of them for grazing purposes have been harmful to the reservation to a marked degree. The conducting of logging operations during the dry season by means of traction engines or by donkey engines and cables have caused numerous fires, some of which have escaped and burned over large areas of the reservation.

In driving sheep to the leased lands within the boundaries of the reservation, they have been grazed for months on the reserved lands, the leasing of the private holdings being primarily an excuse to get the stock within the reservation. It would seem desirable, therefore, that all such holdings be acquired by the Government, in order to eliminate the constant danger arising from them.

We should not overlook the value of the forest reservations as great national parks for recreation and sport, where those so inclined can go and get in touch with nature at her best; where the streams abound in trout, and wild animals are not confined behind iron bars; where there are no signs, 'Keep off the grass,' and, best of all, where one can build himself anew from wholesome mountain air and water, vigorous exercise and plain food.

With so much to commend both State and National reservations and with such vast areas of public lands at the command of the Government, it is somewhat surprising that their realization remained until the last decade of the nineteenth century. At last the forest has gained the resepct due it as a great economic and civilizing factor and is taking its true place in the esteem of all classes of public-spirited citizens.

THE BLOOD OF THE NATION.

A STUDY OF THE DECAY OF RACES THROUGH THE SURVIVAL OF THE UNFIT.—II. IN WAR

By DAVID STARR JORDAN,
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XXV. Not long ago I visited the town of Novara, in northern Italy. There, in a wheatfield, the farmers have plowed up skulls of men till they have piled up a pyramid ten or twelve feet high. Over this pyramid some one has built a canopy to keep off the rain. These were the skulls of young men of Savoy, Sardinia and Austria—men of eighteen to thirty-five years of age, without physical blemish so far as may be, peasants from the farms and workmen from the shops, who met at Novara to kill each other over a matter in which they had very little concern. Should the Prince of Savoy sit on his unstable throne or yield it to some one else, this was the question. It matters not the decision. History doubtless records it, as she does many matters of less moment. But this fact concerns us—here in thousands they died. Farther on, Frenchmen, Austrians and Italians fell together at Magenta, in the same cause. You know the color that we call Magenta, the hue of the blood that flowed out under the olive trees. Go over Italy as you will, there is scarcely a spot not crimsoned by the blood of France, scarcely a railway station without its pile of French skulls. You can trace them across to Egypt, to the foot of the Pyramids. You will find them in Germany—at Jena and Leipzig, at Lützen and Bautzen and Austerlitz. You will find them in Russia, at Moscow; in Belgium, at Waterloo. 'A boy can stop a bullet, as well as a man,' said Napoleon; and with the rest are the skulls and bones of boys, 'ere evening to be trodden like the grass.' 'Born to be food for powder' was the grim epigram of the day, summing up the life of the French peasant. Read the dreary record of the glory of France, the slaughter at Waterloo, the wretched failure of Moscow, the miserable deeds of Sedan, the waste of Algiers, the poison of Madagascar, the crimes of Indo-China, the hideous results of barrack vice and its entail of disease and sterility, and you will understand the 'Man with the Hoe.' The man who is left, the man whom glory cannot use, becomes the father of the future men of France. As the long-horn cattle reappear in a neglected or abused herd of Durhams, so comes forth the aboriginal man, 'the man of the hoe,' in a wasted race of men.

XXVI. A recent French cartoon pictures the peasant of a hundred years ago plowing in a field, a gilded marquis on his back, tapping his gilded snuff-box. Another cartoon shows the French peasant of to-day, still at the plow. On his back is an armed soldier who should be at another plow, while on the back of the soldier rides the second burden of Shylock the money-lender, more cruel and more heavy even than the dainty marquis of the old régime. So long as war remains, the burden of France cannot be shifted.

XXVII. In the loss of war we count not alone the man who falls or whose life is tainted with disease. There is more than one in the man's life. The bullet that pierces his heart goes to the heart of at least one other. For each soldier has a sweetheart, and the best of these die, too—so far as the race is concerned—if they remain single for his sake.

In the old Scottish ballad of the 'Flower of the Forest' this thought is set forth:

> "I've heard the lilting at each ewe-milking
> Lassies a-lilting before the dawn of day.
> But now they are moaning, on ilka green loaning,
> For the 'Flower of the Forest' is a' wed away."

Ruskin once said that 'War is the foundation of all high virtues and faculties of men.' As well might the maker of phrases say that fire is the builder of the forest, for only in the flame of destruction do we realize the warmth and strength that lie in the heart of oak. Another writer, Hardwick, declares that 'War is essential to the life of a nation; war strengthens a nation morally, mentally and physically.' Such statements as these set all history at defiance. War can only waste and corrupt. 'All war is bad,' says Benjamin Franklin, 'some only worse than others.' 'War has its origin in the evil passions of men,' and even when unavoidable or righteous, its effects are most forlorn. The final effect of each strife for empire has been the degradation or extinction of the nation which led in the struggle.

XXIX. Greece died because the men who made her glory had all passed away and left none of their kin, and therefore none of their kind. ''Tis Greece, but living Greece no more,' for the Greek of to-day, for the most part, never came from the loins of Leonidas or Miltiades. He is the son of the stable-boys and scullions and slaves of the day of her glory, those of whom imperial Greece could make no use in her conquest of Asia. "Most of the old Greek race," says Mr. W. H. Ireland, has been swept away, and the country is now inhabited by persons of Slavonic descent. Indeed, there is strong ground for the statement that there was more of the old heroic blood of Hellas in the Turkish army of Edhem Pasha than in the soldiers of King George, who fled before them three years ago." King George himself is only

an alien placed on the Grecian throne to suit the convenience of the outside powers, which to the ancient Greeks were merely factions of barbarians. In the late war some poet, addressing the spirit of ancient Greece, appealed to her

> "Of all thy thousands grant us three
> To make a new Thermopylæ."

But there were not even three—not even one—'to make another Marathon,' and the Turkish troops swept over the historic country with no other hindrance than the effortless deprecation of Christendom.

XXX. Why did Rome fall? It was not because untrained hordes were stronger than disciplined legions. It was not that she grew proud, luxurious, corrupt, and thereby gained a legacy of physical weakness. We read of her wealth, her extravagance, her indolence and vice, but all this caused only the downfall of the enervated, the vicious and the indolent. The Roman legions did not riot in wealth. The Roman generals were not all entangled in the wiles of Cleopatra.

XXXI. 'The Roman Empire,' says Seeley, 'perished for want of men.' You will find this fact on the pages of every history, though few have pointed out war as the final and necessary cause of the Roman downfall. In his recent noble history of the 'Downfall of the Ancient World' ('Der Untergang der Antiken Welt,' 1897), Prof. Otto Seeck,* of Greifeswald, makes this fact very apparent. The cause of the fall of Rome is found in the 'Extinction of the Best' ('Die Ausrottung der Besten'), and all that remains to the historian is to give the details of this extermination. He says 'In Greece a wealth of spiritual power went down in the suicidal wars.' In Rome "Marius and Cinna slew the aristocrats by hundreds and thousands. Sulla destroyed no less thoroughly the democrats, and whatever of noble blood survived fell as an offering to the proscription of the triumvirate." "The Romans had less of spontaneous power to lose than the Greeks, and so desolation came to them all the sooner. He who was bold enough to rise politically was almost without exception thrown to the ground. *Only cowards remained, and from their brood came forward the new generations.* Cowardice showed itself in lack of originality and slavish following of masters and traditions." Had the Romans been still alive, the Romans of the old republic, neither inside nor outside forces could have worked the fall of Rome. But the true Romans passed away early. Even Cæsar notes the 'dire scarcity of men.' "*δεινὴν ὀλιγανθροπίαν.*") Still there were always men in plenty, such as they were. Of this there is abundant testimony. Slaves and camp followers were always in evidence. It was the men of strength and

* I am indebted to Prof. E. A. Ross for the reference to this excellent work.

character, 'the small farmers,' the 'hardy dwellers on the flanks of the Apennines,' who were gone.

"The period of the Antonines was a period of sterility and barrenness. The human harvest was bad." Augustus offered bounties on marriage until 'Celibacy became the most comfortable and most expensive condition of life.' "Marriage," says Metellus, "is a duty which, however painful, every citizen ought manfully to discharge."

"The mainspring of the Roman army," says Hodgkin, "for centuries had been the patient strength and courage, capacity for enduring hardships, instinctive submission to military discipline of the population which lined the ranges of the Apennines."

Berry states that an "effect of the wars was that the ranks of the small farmers were decimated, while the number of slaves who did not serve in the army multiplied." Thus *'Vir gave place to Homo,'* real men to mere human beings.

With the failure of men grew the strength of the mob, and of the emperor, its exponent. "The little finger of Constantine was stronger than the loins of Augustus." At the end "the barbarians settled and peopled the Roman Empire rather than conquered it." "The Roman world would not have yielded to the barbaric were it not decidedly inferior in force." Through the weakness of men, the Emperor assumed divine right. Dr. Zumpt says, "Government having assumed godhead, took at the same time the appurtenances of it. Officials multiplied. Subjects lost their rights. Abject fear paralyzed the people, and those that ruled were intoxicated with insolence and cruelty."

"The Emperor," says Professor Seeley, "possessed in the army an overwhelming force over which citizens had no influence, which was totally deaf to reason or eloquence, which had no patriotism, because it had no country, which had no humanity, because it had no domestic ties." "There runs through Roman literature a brigand's and a barbarian's contempt for honest industry." "The worst government is that which is most worshipped as divine."

So runs the word of the historian. The elements are not hard to find. Extinction of manly blood; extinction of freedom of thought and action; increase of wealth gained by plunder; loss of national existence.

XXXII. So fell Greece and Rome, Carthage and Egypt, the Arabs and the Moors, because, their warriors dying, the nation bred real men no more. The man of the strong arm and the quick eye gave place to the slave, the pariah, the man with the hoe, whose lot changes not with the change of dynasties.

XXXIII. Other nations of Europe may furnish illustrations in greater or less degree. Germany guards her men, and reduces the waste of war to a minimum. She is 'military, but not warlike,' and this dis-

tinction means a great deal from the point of view of this discussion. In modern times the greatest loss of Germany has been not from war, but from emigration. If the men who have left Germany are of higher type than those who remain at home, then the blood of the nation is impoverished. That this is the case the Germans in Germany are usually not willing to admit. On the other hand, those competent to judge the German-American find no type of men in the Old World his mental or physical superior.

The tendency of emigration, whether to cities or to other countries, is to weaken the rural population. An illustration of the results of checking this form of selection is seen in the Bavarian town of Oberammergau. This little village, with a population not exceeding fifteen hundred, has a surprisingly large number of men possessing talent, mental and physical qualities far above the average even in Germany. The cause of this lies in the Passion Play, for which for nearly three centuries Oberammergau has been noted. The best intellects and the noblest talents that arise in the town find full scope for their exercise in this play. Those who are idle, vicious or stupid are excluded from it. Thus, in the long run, the operation of selection is to retain those whom the play can use and to exclude all others. To weigh the force of this selected heredity we have only to compare the quality of Oberammergau with that of other Bavarian towns, as, for example, her sister village of Unterammergau, some two miles lower down, in the same valley.

XXXIV. Switzerland is the land of freedom—the land of peace. But in earlier times some of the thrifty cantons sent forth their men as hireling soldiers to serve for pay under the flag of whomsoever might pay their cost. There was once a proverb in the French Court, 'pas d'argent; pas de Suisses,' no money; no Swiss, for the agents of the free republic drove a close bargain.

In Luzerne stands one of the noblest monuments in all the world, the memorial of the Swiss guard of Louis XVI., killed by the mob at the palace of Versailles. It is carved in the solid rock of a vertical cliff above a great spring in the outskirts of the city. A lion of heroic size, a spear thrust through its body, guarding in its dying paws the Bourbon lilies and the shield of France. And the traveler, Carlyle tells us, should visit Luzerne and her monument, "Not for Thorwaldsen's sake alone, but for the sake of the German Biederkeit and Tapferkeit, the valor which is worth and truth, be it Saxon, be it Swiss."

Beneath the lion are the names of those whose devotion it commemorates. And with the thought of their courage comes the thought of the pity of it, the waste of brave life in a world that has none too much. It may be fancy, but it seems to me that as I go about in Switzerland I can distinguish by the character of the men who remain those

cantons who sent forth mercenary troops from those who kept their own for their own upbuilding. Perhaps for other reasons than this Lucerne is weaker than Graubünden, and Unterwalden less virile than little Appenzell. In any event, the matter is worthy of consideration, for this is absolutely certain: just in proportion to its extent and thoroughness is military selection a cause of decline.

XXXV. Holland has become a nation of old men, rich, comfortable and unprogressive. Her sons have died in the fields of Java, the swamps of Achin, wherever Holland's thrifty spirit has built up nations of slaves. It is said that Batavia alone has a million of Dutch graves. The armies of Holland to-day are recruited in every port. Dutch blood is too precious to be longer spilled in her enterprises.

XXXVI. Spain died of empire centuries ago. She has never crossed our path. It was only her ghost which walked at Manila and Santiago. In 1630, the Augustinian friar La Puente thus wrote of the fate of Spain: "Against the credit for redeemed souls I set the cost of Armadas and the sacrifice of soldiers and friars sent to the Philippines. And this I count the chief loss, for mines give silver, and forests give timber, but only Spain gives Spaniards, and she may give so many that she may be left desolate and constrained to bring up strangers' children instead of her own." "This is Castile," said a Spanish knight; "she makes men and wastes them." "This sublime and terrible phrase," says Lieutenant Carlos Gilman Calkins, from whom I have received both these quotations, "sums up Spanish history."

The warlike nation of to-day is the decadent nation of to-morrow. It has ever been so, and in the nature of things it must ever be.

XXXVII. In his charming studies of 'Feudal and Modern Japan,' Mr. Arthur Knapp returns again and again to the great marvel of Japan's military prowess after more than two hundred years of peace. It is astonishing to him that after more than six generations in which physical courage has not been demanded, these virile virtues should be found unimpaired. We can readily see that this is just what we should expect. In times of peace there is no slaughter of the strong, no sacrifice of the courageous. In the peaceful struggle for existence there is a premium placed on these virtues. The virile and the brave survive. The idle, weak and dissipated go to the wall. If after two hundred years of incessant battle Japan still remained virile and warlike, that would indeed be the marvel. But that marvel no nation has ever seen. It is doubtless true that warlike traditions are most persistent with nations most frequently engaged in war. But the traditions of war and the physical strength to gain victories are very different things. Other things being equal, the nation which has known least of war is the one most likely to develop the 'strong battalions' with whom victory must rest.

XXXVIII. What shall we say of England and her hundred petty wars 'smouldering' in every part of the globe?

Statistics we have none, and no evidence of tangible decline that Englishmen will not indignantly repudiate. Besides, in the struggle for national influences, England has had many advantages which must hide or neutralize the waste of war. In default of facts unquestioned, we may appeal to the poets, letting their testimony as to the reversal of selection stand for what it is worth. Kipling tells us of the cost of the rule of the sea:

"We have fed our sea for a thousand years,
And she calls us, still unfed;
Though there's never a wave of all her waves
But marks our English dead."

"If blood be the price of admiralty,
Lord God, we have paid it in full."

Again, referring to dominion on land, he says:

"Walk wide of the widow of Windsor,
For half of creation she owns,
We've bought her the same with the sword and the flame,
And we've salted it down with our bones.
Poor beggars, it's blue with our bones."

Finer than this are the lines in the 'Revelry of the Dying,' written by a British officer, Bartholomew Dowling, it is said, who died in the plague in India:

"Cut off from the land that bore us,
Betrayed by the land we find;
When the brightest are gone before us
And the dullest are left behind.
So stand to your glasses steady,
Tho' a moment the color flies,
Here's a cup to the dead already
And huzza for the next that dies!"

The stately "Ave Imperatrix' of Oscar Wilde, the last flicker of dying genius in his wretched life, contains lines that ought not to be forgotten:

"O thou whose wounds are never healed,
Whose weary race is never run;
O Cromwell's England, must thou yield
For every foot of ground a son?

"What matter if our galleys ride
Pine forest-like on every main;
Ruin and wreck are at our side,
Stern warders of the house of pain.

"Where are the brave, the strong, the fleet,
The flower of England's chivalry?
Wild grasses are their winding sheet,
And sobbing waves their threnody.

"Peace, peace, we wrong our noble dead
To vex their solemn slumber so;
But childless and with thorn-crowned head,
Up the steep road must England go!"

We have here the same motive, the same lesson which Byron applies to Rome:

"The Niobe of Nations—there she stands,
Crownless and childless in her voiceless woe,
An empty urn within her withered hands,
Whose sacred dust was scattered long ago!"

XXXIX. It suggests the inevitable end of all empire, of all dominion of man over man by force of arms. More than all who fall in battle or are wasted in the camps, the nation misses the 'fair women and brave men' who should have been the descendants of the strong and the manly. If we may personify the spirit of the nation, it grieves most not over its 'unreturning brave,' but over those who might have been, but never were, and who, so long as history lasts, can never be.

XL. Against this view is urged the statement that the soldier is not the best, but the worst, product of the blood of the English nation. Tommy Atkins comes from the streets, the wharves, the graduate of the London slums, and if the empire is 'blue with his bones,' it is, after all, to the gain of England that her better blood is saved for home consumption, and that, as matters are, the wars of England make no real drain of English blood.

In so far as this is true, of course the present argument fails. If war in England is a means of race improvement, the lesson I would read does not apply to her. If England's best do not fall on the field of battle, then we may not accuse war of their destruction. The fact could be shown by statistics. If the men who have fallen in England's wars, officers and soldiers, rank and file, are not on the whole fairly representative of 'the flower of England's chivalry,' then fame has been singularly given to deception. We have been told that the glories of Blenheim, Trafalgar, Waterloo, Majuba Hill, were won by real Englishmen. And this in fact is the truth. In every nation of Europe the men chosen for the army are above the average of their fellows. The absolute best doubtless they are not; but still less are they the worst. Doubtless, too, physical excellence is more considered than moral or mental strength, and certainly again the more noble the cause, the more worthy the class of men who will risk their lives for it.

Not to confuse the point by modern instances, it is doubtless true

that better men fell on both sides when 'Kentish Sir Byng stood for the King' than when the British arms forced the opium trade on China. No doubt, in our own country, better men fell at Bunker Hill or Cowpens than at Cerro Gordo or Chapultepec. The lofty cause demands the lofty sacrifice.

It is the shame of England that most of her many wars in our day have cost her very little. They have been scrambles of the mob or with the mob, not triumphs of democracy.

There was once a time when the struggles of armies resulted in a survival of the fittest, when the race was indeed to the swift and the battle to the strong. The invention of 'villainous gunpowder' has changed all this. Except the kind of warfare called guerrilla, the quality of the individual has ceased to be much of a factor. The clown can shoot down the hero and 'doesn't have to look the hero in the face as he does so.' The shell destroys the clown and hero alike, and the machine gun mows down whole ranks impartially. There is little play for selection in modern war save what is shown in the process of enlistment.

XLI. America has grown strong with the strength of peace, the spirit of democracy. Her wars have been few. Were it not for the mob spirit, they would have been still fewer, but in most of them she could not choose but fight. Volunteer soldiers have swelled her armies, men who went forth of their own free will, knowing whither they were going, believing their acts to be right, and taking patiently whatever the fates may hold in store.

The feeling for the righteousness of the cause, "with the flavor of religion in it," says Charles Ferguson, "has made the volunteer the mighty soldier he has always been since the days of Naseby and Marston Moor." Only with volunteer soldiers can democracy go into war. When America fights with professional troops, she will be no longer America. We shall then be, with the rest of the militant world, under mob rule. "It is the mission of democracy," says Ferguson again, "to put down the rule of the mob. In monarchies and aristocracies it is the mob that rules. It is puerile to suppose that kingdoms are made by kings. The king could do nothing if the mob did not throw up its cap when the king rides by. The king is consented to by the mob because of that which in him is mob-like. The mob loves glory and prizes. So does the king. If he loved beauty and justice, the mob would shout for him while the fine words were sounding in the air; but he could never celebrate a jubilee or establish a dynasty. When the crowd gets ready to demand justice and beauty, it becomes a democracy, and has done with kings."

It was at Lexington that the embattled farmers 'fired the shot that was heard around the world.' To them life was of less value than a

principle, the principle written by Cromwell on the statute book of Parliament: 'All just powers under God are derived from the consent of the people.' Since this war many patriotic societies have arisen, finding their inspiration in personal descent from those who fought for American independence. The assumption, well justified by facts, is that these were a superior type of men, and that to have had such names in our personal ancestry is of itself a cause for thinking more highly of ourselves. In our little private round of peaceful duties, we feel that we might have wrought the deeds of Putnam and Allen, of Marion and Greene, of our revolutionary ancestors, whoever they may have been. But if those who survived were nobler than the mass, so also were those who fell. If we go over the record of brave men and wise women whose fathers fought at Lexington, we must think also of the men and women who shall never be, whose right to exist was cut short at this same battle. It is a costly thing to kill off men, for in men alone can national greatness consist.

XLII. But sometimes there is no other alternative. It happened once that for 'every drop of blood drawn by the lash another must be drawn by the sword.' It cost us a million of lives to get rid of slavery. And this million, North and South, was the 'best that the nation could bring.' North and South, the nation was impoverished by the loss. The gaps they left are filled to all appearance. There are relatively few of us left to-day in whose hearts the scars of forty years ago are still unhealing. But a new generation has grown up of men and women born since the war. They have taken the nation's problems into their hands, but theirs are hands not so strong or so clean as though the men that are stood shoulder to shoulder with the men that might have been. The men that died in 'the weary time' had better stuff in them than the father of the average man of to-day.

Read again Brownell's rhymed roll of honor, and we shall see its deeper meaning:

Allen, who died for others,
  Bryan of gentle fame,
And the brave New England brothers
  Who have left us Lowell's name;
Bayard, who knew not fear,
  True as the knight of yore,
And Putnam and Paul Revere,
  Worthy the names they bore.
Wainwright, steadfast and true,
  Rodgers of brave sea-blood,
And Craven, with ship and crew,
  Sunk in the salt-sea flood.
Terrill, dead where he fought,
  Wallace, that would not yield;
Sumner, who vainly bought
  A grave on the foughten field,

But died ere the end he saw,
With years and battles outworn;
There was Harmon of Kennesaw,
And Ulric Dahlgren, and Shaw
That slept with his Hope Forlorn.
Lytle, soldier and bard,
And the Ellets, sire and son,
Ransom, all grandly scarred,
And Redfield, no more on guard;
But Alatoona is won!

So runs the record, page after page:

"All such, and many another,
Ah, list, how long to name!"

And these were the names of the officers only. Not less worthy were the men in the ranks. It is the paradox of democracy that its greatness is chiefly in the ranks. "Are all the common men so grand, and all the titled ones so mean?"

XLIII. North or South, it was the same. 'Send forth the best ye breed' was the call on both sides alike, and to this call both sides alike responded. As it will take 'centuries of peace and prosperity to make good the tall statures mowed down in the Napoleonic wars,' so like centuries of wisdom and virtue are needed to restore to our nation its lost inheritance of patriotism. Not the capacity for patriotic talk, for of that there has been no abatement, but of that faith and truth which 'on war's red touchstone rang true metal.' With all this we can never know how great is our real misfortune, nor see how much the men that are fall short of the men that ought to have been.

It will be said that all this is exaggeration, that war is but one influence among many, and that each and all of these forms of destructive selection may find its antidote. This is very true. The antidote is found in the spirit of democracy, and the spirit of democracy is the spirit of peace. Doubtless these pages constitute an exaggeration. They were written for that purpose. I would show the 'ugly, old and wrinkled truth stripped clean of all the vesture that beguiles.' To see anything clearly and separately is to exaggerate it. The naked truth is always a caricature unless clothed in conventions, fragments taken from lesser truths. The moral law is an exaggeration, 'The soul that sinneth it shall die.' Doubtless one war will not ruin a nation; doubtless it will not destroy its virility or impair its blood. Doubtless a dozen wars may do all this. The difference is one of degree alone; I wish only to point out the tendency. That the death of the strong is a true cause of the decline of nations is a fact beyond cavil or question. The 'man who is left' holds always the future in his grasp. One of the great books of our new century will be some day written on the selection of men, the screening of human life through the actions of man and the operation

of the institutions men have built up. It will be a survey of the stream of social history, its whirls and eddies, rapids and still waters, and the effect of each and all of its condtions on the heredity of men. The survival of the fit and the unfit in all degrees and conditions will be its subject matter. This book will be written, not roughly and hastily, like the present fragmentary essay, still less will it be a brilliant effort of some analytical imagination. It will set down soberly and statistically the array of facts which as yet no one possesses, and the new Darwin whose work it shall be must, like his predecessor, spend twenty-five years in the gathering of 'all facts that can possibly bear on the question.' When such a book is written, we shall know for the first time the real significance of war.

XLIV. If any war is good, civil war must be best. The virtues of victory and the lessons of defeat would be kept within the nation. This would protect the nation from the temptation to fight for gold or trade. Civil war under proper limitations could remedy this. A time limit could be adopted, as in football, and every device known to the arena could be used to get the good of war and to escape its evils.

For example, of all our States New York and Illinois have doubtless suffered most from the evils of peace, if peace has evils which disappear with war. They could be pitted against each other, while the other States looked on. The 'dark and bloody ground' of Kentucky could be made the arena. This would not interfere with trade in Chicago, nor soil the streets in Baltimore. The armies could be filled up from the ranks of the unemployed, while the pasteboard heroes of the national guard could act as officers. All could be done in decency and order, with no recriminations and no oppression of an alien foe. We should have all that is good in war, its pomp and circumstance, the 'grim resolution of the London clubs,' without war's long train of murderous evils. Who could deny this? And yet who could defend it?

If war is good, we should have it regardless of its cost, regardless of its horrors, its sorrows, its anguish, havoc and waste.

But it is bad, only to be justified as the last resort of 'mangled, murdered liberty,' a terrible agency to be evoked only when all other arts of self-defense shall fail. The remedy for most ills of men is not to be sought in 'whirlwinds of rebellion that shake the world,' but in peace and justice, equality among men, and the cultivation of those virtues we call Christian, because they have been virtues ever since man and society began, and will be virtues still when the era of strife is past, and the 'redcoat bully in his boots' no longer 'hides the march of man from us.'

It is the voice of political wisdom which falls from the bells of Christmas-tide: "Peace on earth; good will towards men!"

PROGRESS AND TENDENCY OF MECHANICAL ENGINEERING IN THE NINETEENTH CENTURY.—II.

By Professor ROBERT H. THURSTON,
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IN 1800, Galvani and Volta had sewed the seed, and since has sprung up the whole science and art of electrical physics. Ten years ago we had about 700 miles of electric railway; to-day about 15,000 miles are in operation in the United States alone; a thousand millions of dollars are invested in the stock, and an army of two hundred thousand men is employed by them, mainly in the great cities, but with steady growth towards all sections and into all aggregations of population. Two thousand millions of dollars are reported to be now invested in apparatus of electrical distributions of energy, converted ultimately into light and power. About two-thirds of a *billion* of dollars are invested in the property of the electric light companies. We have between one and two million miles of telephone wire, and can talk from Boston to Chicago; from Chicago to San Francisco will soon be found an easy conversational distance. The Bell Company alone owns a million miles of wire, a million and a half instruments, and receives six millions of dollars a year from its business. The world, outside the United States, utilizes not quite as much capital in this most wonderful of the inventions of the century as does our own country, having about a half-million exchanges to our six hundred thousand and over on the Bell system alone.

Of steam power, about twenty millions of the engineers' 'horse-power,' the equivalent of perhaps seventy-five, or even possibly more nearly a hundred, millions of horse-power developed by animal forces, move the fleets of the world, merchant and naval, and drive our ships across every sea. It even has been found practicable to apply steam-power to the sewing machine, and of the million or more manufactured in the United States and the fifty per cent. added to the total by other nations, a very considerable fraction are operated by steam-power, and of the hundred thousand people engaged in its manufacture and the millions engaged in its use, a corresponding proportion are aided by this mighty engine of civilization. Steam supplies the power for driving the machinery which produces a quarter of a million mowers and reapers in the United States—an unknown industry a century ago—and thus, with the help of the steam-plow and other machinery of agriculture, all inventions of the century, secures for the nation a foreign market for

two hundred millions of dollars' worth of grain and flour, a surplus left us after feeding our own population as the people of no other country are, or ever were, fed. Farms of tens of thousands of acres in area can now be thus cheaply cultivated.

Electrical engineering is to-day one of the most impressive of all modern developments in mechanical engineering, and the whole world is coming to be served by the installation of the machinery of our light and power distribution 'plants.' While it is true, as often remarked, that electrical engineering is not only a department of mechanical engineering, but one which involves, in large proportion, design, construction and operation in the more familiar departments of mechanical engineering as fundamental bases, it is none the less true that electrical engineering is most closely approximate to pure science and most distinctive in its own character among all specialties taken up by the engineer as individual vocations. The machinery of the business involves all the principles of design and construction taught the mechanical engineer, and the scientific side, once almost purely such, now attaches itself to the mechanical as a lesser to a greater. The whole of this enormous accession to the world's industries has come in within the last half-century, practically, and the telegraph, the telephone, the electric light and the electric railway have succeeded one another since that date. The last is the outcome of the last quarter-century.

The energy which carries the telegram along the wires to-day comes from the steam-engine, which is now a principal and most absolutely essential element; telephones, like telegraph instruments, are the output of most extensive and important manufacturing establishments; electric light and power distributions are all systems of distribution of the power of the steam-engine. To-day there are probably $3,000,000,000 invested, in our country alone, in telegraphs, telephones and electric distributions, of which the larger part by far is invested in the latter. In fact, Mr. T. C. Martin reckons a still larger total, and computes these figures: telegraph, $250,000,000; telephones, $300,000,000; electric lighting, $1,200,000,000; electric railways, $1,800,000,000; other uses of electric power, $250,000,000; manufacturing, $150,000,000; storage batteries, etc., $25,000,000; total, $3,975,000,000, about four thousand millions, nearly four *billions*, of dollars.

More seductive even than the problems of the electrical engineer, more deceitfully promising than any one of the great problems of the age, seemingly more completely solved in its subsidiary elements and almost on the very verge of solution, completely and perfectly, is the task assigned the inventor from the earliest days of the world, from the day when the first man saw the first bird rise from under his feet and wing its way toward the heavens, safe, free and joyous: the problem of aërodromics, of aviation and aëronautics. Inventors attacked this prob-

lem in prehistoric times, and have never ceased their endeavors; for there is no invention, and never has been imagined an invention more attractive to the mind of man; nor is there any invention the perfection of which would have more interest for mankind or illustrate more splendidly the triumph of the mind of man over the conditions which hem him in. Yet the century which has seen such marvelous, almost catastrophic, evolutions in all other fields has seen its end without final success here.

Yet some important advances have been made. The dirigible balloon has become capable of contending with moderate winds, and of traversing still air in any direction at moderate speed and for small distances; the balloon itself and its motors are taking definite form and standard proportions, especially in the hands of the military staff of the armies of European nations. Our own army officers have not, so far as known, entered upon this task, though having at hand the most royal inventors of the world. Count Zeppelin probably illustrates the furthest advance in this department.

In aërodromics, Professor Langley has completely developed the fundamental principles of self-sustaining flight, and has revealed the fact that there are far fewer and far less formidable obstacles to be overcome in this direction than had been previously supposed. His researches are the classics of this division of applied science, and his experimental investigations of the laws of this science will permanently stand as the first important steps in the development of the rational basis of all future work, and as the foundations of aërodromic science; while his extraordinary work in the practical evolution of the aërodrome —the more wonderful as the work of a scientific man whose vocations, and until recently whose avocations, have been in quite other departments than those of mechanical construction—will always remain famous as the first deliberate and successful attempt to carry into practice principles thus revealed. In the nineteenth century, we may at least claim, these first advances on firm grounds have been effected, and we need not be at all surprised if, in the earlier years of the new century, complete success, so far as the mechanical engineering of the case is concerned, shall be attained. There is some reason to doubt whether commercial success will follow—not that it is in itself inherently impossible, but that it is a question whether, in the presence of the competition of the more advantageous methods of transportation on solid land and with the buoyant and hardly less effective support of the ocean wave, conveyance of passengers and of merchandise can not always be generally effected vastly more safely and cheaply. Yet that there will be found a place and purpose for aviation, in time of war if not in time of peace, and even probably for profitable employment, we may not doubt.

Steam is apparently coming, as the various other motor-fluids are, into use on the highway, and, after an interregnum of a half-century or more, due to the stupidity of legislators mainly, the automobile, in innumerable forms and on innumerable 'systems,' is once again displacing the horse in city streets and, in less degree, perhaps, on country roads, and is promising ere long to do a large part of our transportation of merchandise over short routes and off the line of the railway. Thousands are now in use in this country and abroad, and tens—hundreds, nominally—of millions of dollars are invested in their manufacture.

In infinite variety the progress of invention thus reveals itself. Individuals, nations, even continents and worlds have courses like that of the rocket: rising with rapid acceleration, upward and onward, to a culmination, when a sudden development of energy from latent form occurs, and a brilliant illumination for the moment surprises and enlightens us; then the limit is attained, the path curves over and downward, and after a brief period, downward acceleration begins and its career presently comes to an end. This is not the history of invention, which is never self-limited; a step made is never retraced. The progress of the day is not only recorded in written and printed history and permanently preserved, but is given a still more permanent record in the life and habits and traditions of the people, and each invention and each new advance is the basis of a later and still higher progress. The only limit to be expected to this advancement of civilization, through invention and the mechanic arts, is that set by some catastrophe which shall ultimately involve the life of the race, having its source in natural evolutions of a physical character, and bringing to an end all the activities of mankind in some probably far-distant generation.

The extent to which the specialization consequent upon the changes in the mechanism and methods of manufactures have progressed during the century just past, may be realized more fully when it is understood that, for example, in the making of a watch, there may be fifteen or sixteen hundred operations conducted with the help of five or six hundred machines by as many operatives, each of whom necessarily acquires wonderful expertness in tasks thus repeated constantly, hour by hour, day by day, throughout the working day and the calendar year. These movements become intuitive and automatic; their accuracy and rapidity become almost incredible, and the human machine, through its internal automatism, thus relieves the mind and gives it freedom from stress and fatigue in a manner unknown to the worker of earlier days. The labor-assisting machinery also thus enables the operative to produce, without serious toil and fatigue, from ten to a hundred times as much of his special product as could his unaided predecessor in the vocation with, however, more concentrated attention giving far less skill and accuracy. The inventor and the mechanic thus illustrate the immense

difference in value and efficiency to be observed between work of brain and work of muscle alone.

Meantime the worker receives larger wages; each dollar will buy more of the necessaries of life, vastly more of its comforts. Clothing is better, cheaper and more plentiful; food is better, of greater variety and is easier obtained; wages have gone up and prices have gone down; the average citizen finds it easier to secure employment at remunerative wages; he secures a larger and a larger proportion of the earnings of capital and labor, and he obtains more opportunities for incidental profit and for paying investments of his more easily acquired savings. The savings banks of the country are now finding difficulty in caring for his accumulations, while the larger capitalist is finding no less difficulty in securing a fair return on invested capital in large amounts.

Twenty years ago, when preparing the second annual address of the then President of the American Society of Mechanical Engineers, I wrote:*

"I have sometimes said that the world was waiting for the appearance of three great inventors, yet unknown, for whom it has in store honors and emoluments far exceeding all ever yet accorded to any one of their predecessors.

"The first is the man who is to show how, by the consumption of coal, we may directly produce electricity, and thus, perhaps, evade that now inevitable and enormous loss that comes of the utilization of energy in all heat-engines driven by substances of variable volume. Our electrical engineers have this great step still to take, and are apparently not likely soon to gain the prize that may yet reward some genius yet to be born.

"The second of these greatest inventors is he who will teach us the source of the beautiful soft-beaming light of the firefly and the glow-worm, and will show us how to produce this singular illuminant, and to apply it with success practically and commercially. This wonderful light, free from heat and from consequent loss of energy, is nature's substitute for the crude and extravagantly wasteful lights of which we have, through so many years, been foolishly boasting. The dynamo-electrical engineer has nearly solved this problem. Let us hope that it may be soon fully solved, and by one of those among our own colleagues who are now so earnestly working in this field, and that we may all live to see him steal the glow-worm's light, and to see the approaching days of Vril predicted so long ago by Lord Lytton.

"The third great genius is the man who is to fulfil Darwin's prophecy (1759), closing the stanza:

> "Soon shall thy arm, unconquered steam, afar
> Drag the slow barge or drive the rapid car,
> Or, on wide-waving wings expanded bear
> The flying chariot through the fields of air."

Of these three inventors none has yet appeared, and their coming may prove to be the great events of the twentieth century. The task set for the first has been often attacked by later men of science, and especially the chemists; but, while some real progress has been made, the purpose of this inventor is not accomplished and seems little, if any,

*Trans. Am. Soc. M. E.—1881.

nearer accomplishment than at the end of the last quarter-century. But the time will yet come, we at least may reasonably hope, if not predict, when a way will be found thus to increase the availability of the stored energy of our fuel deposits, until they shall furnish ten times the power and energy now obtainable from each ton of fuel; thus correspondingly lengthening the period of human life and work in the temperate regions of the earth. Were this to-day possible, the endurance of the Pennsylvania coal-beds as sources of power would be lengthened from the present anticipated century to a millennium, and the thirtieth century, instead of only the twentieth, would profit by them. Great Britain might hope to continue a manufacturing nation for five centuries to come, and the world might gain ten times as much permanent wealth, by its use of the latent energy of fuel, as now seems possible.

The mechanical engineer, the electrician and the chemist have here an incentive to a most magnificent task and a noble rivalry.

The second of our great triumvirate of inventors or discoverers is more certainly coming. His advent is indicated by the electrical engineer and the physicist in their use of electrical energy of enormously high tension; while the biological chemist is now a close second in the race, through his researches in the field of low-temperature combustion and amongst the animal forms producing light and electricity without heat—the animal machines in which the processes of nature are seen already accomplishing the task. This being done, the engineer will be able to reduce the cost of lighting, as measured in power, to one-twentieth its present amount, and as measured in fuel, if he can combine these two improvements effectively, to one-two-hundredth its amount to-day, proportionally reducing the intimidating waste now going on in our deposits of irreplaceable natural stores of power.

The third inventor is also here with a crude beginning of his task, and while, at the commencement of the nineteenth century, he was a subject of unsparing ridicule, and even sometimes by able men within the last decade, he would be a bold man who should to-day dare to assert the improbability of the coming century seeing the problem solved, so far as its engineering is concerned. The commercial problem must be left to take care of itself—as it always has done hitherto.

All these are evidently problems affecting vitally all progress in the future of energy-production in the field of mechanical engineering. When complete conversion of energy is effected by any mechanism employing our natural sources of energy, the task of the builder of the air-ship is rendered less difficult, the cost of light-production is made easier and the utilization of the latent energy of fuel through the heat-engine is made comparatively insignificant in cost.

This much is revealed to us through 'The Great Discovery of the Age,' as some one has rightly called it: the discovery and experimentally

confirmed 'Law of Substance,' as Haeckel denominates it, the principle in nature which I enunciated a quarter of a century ago thus:

"All that exists, whether matter or force, or their product, energy, and in whatever form, is indestructible except by the infinite power which has created it."*

This principle, probably as old as Aristotle, or older, enunciated by Cicero when he declared, " One eternal and immutable law embraces all things and all times;" experimentally proved, at least qualitatively, by Rumford in the latter part of the eighteenth century, confirmed by Davy, proved and quantitatively illustrated by Mayer, by Joule and by Rowland and numerous contemporary investigators, the Law of Substance of Haeckel, is itself a nineteenth century product and the basis of our whole system of energy production, transmutation and transmission, the foundation of the whole superstructure in mechanical engineering and of its wealth-production, and of human progress and higher human life.

Education in applied science and in the principles directly underlying the work of the engineer, in common schools, secondary schools and professional schools and colleges, an education which has seen as much improvement as have the arts and sciences themselves, has had much to do with the later progress of mechanical engineering, especially in the United States. Systematic instruction in the departments of mechanical engineering, such as is now obtainable by almost any young man determined to secure it, not only has much to do with our progress at the moment, but it is this phase of education, in our state colleges particularly, which is settling the tendency of the flow of the rising tide for the immediate future, and probably for all coming time. Although it has been a force of recognized importance and influence for less than a single generation, and has had a distinct and special position among 'the educations' for a very brief period, it has already done much to correct the defects of the industrial system of our country—still more that of France and that of Germany, hardly less that of Great Britain—and also to systematize our industries. The discoveries of science and the inventions of our mechanics furnish material to be utilized by the alumni of our technical and professional schools and colleges as they can be by no other class in the community; the scientific method of the schools and the scientific knowledge of their graduates, and the hands and brains of the new leaders of the industrial army give perfected organization and improved administration to every branch of the great economical, machine-like, modern industrial sys-

* Proceedings of Am. Assoc. for Advancement of Science, 1878; Vice-Presidential Address: 'The Scientific Method of Advancement of Science.'—R. H. T.

Also 'Manual of the Steam-Engine,' Vol. I, Chap. IV, § 75, p. 299, THE POPULAR SCIENCE MONTHLY, March, 1901.

tem. Even where these well-trained officers are not in command, their influence is felt, and every member of the organization works in accordance with their more efficient systems. The whole nation is rapidly learning how to make the most and best of its powers, as well as how to profit by growing opportunities and acquisitions.

Thomas Huxley, admittedly an authority on the subject of scientific training, said, in his Mason College address:

"Neither the discipline nor the subject-matter of classical education is of such direct value to the student of physical science as to justify the expenditure of valuable time on either." . . . "For the purpose of attaining real culture, an exclusively scientific education is at least as effectual as an exclusively literary education."

Huxley was a member of nearly all the royal commissions on education of his time, and had large opportunities for observation and investigation in this field. His views were founded on extensive and rare experience and sound knowledge; none could speak with greater authority. He says in one of his addresses on this subject:

"The great mass of mankind have neither the liking nor the aptitude for either literary or scientific or artistic pursuits; nor, indeed, for excellence of any sort. Their ambition is to go through life with moderate exertion and a fair share of ease, doing common things in a common way. And a great blessing and a comfort it is that the majority of men are of this mind; for the majority of things to be done are common things, and are quite well enough done when commonly done. The great end of life is not knowledge, but action. What men need is as much knowledge as they can assimilate and organize into a basis for action; give them more and it may become injurious. One knows people who are heavy and stupid from undigested learning, as others are from over-fulness of meat and drink. But a small percentage of the population is born with that most excellent quality, the desire for excellence, or with special aptitude of some sort or other. . . . Now, the most important object of all educational schemes is to catch those exceptional people and turn them to account for the good of society. No man can say where they will crop up; like their opposites, the fools and the knaves, they appear sometimes in the palace, sometimes in the hovel; but the great thing aimed at, I was almost going to say the important end of all social arrangements, is to keep these glorious sports of Nature from being corrupted by luxury or starved by poverty, and to put them into the positions in which they can do the work for which they are specially fitted. . . . I weigh my words well when I say that if the nation could purchase a potential Watt or Davy or Faraday at the cost of a hundred thousand pounds down, he would be dirt cheap at the money." *

But our modern educations are producing many Watts and Davys and Faradays, and as progress continues and research becomes more and more the privilege of these 'glorious sports of Nature,' and as more and more men of genius become revealed by systematic, scientific education, the outcome must inevitably be a vastly more complete exploration of

* Mitchell's sketch of The Life and Work of Huxley; Leaders in Science Series; Putnams; 1900; Chap. XI.

the hidden mysteries of natural phenomena and continually more and more rapid development of these as yet unexplored mines. Our Watts and Davys and Faradays are already gradually discovering the secrets of Nature's production of light without heat, of heat without wastes, of electricity within minimum weight and space, making all elements subservient with at least similar, if not equal, effectiveness with that measured by them in the animal machine—the animal machine, still concealing from them many a secret, must soon reveal all, and permit many later Watts and Davys and Faradays to make our stores of natural energies of multifold value and efficiency in the performance of the tasks of the future.

The outcome of the century, so far as our methods of education are concerned, has been the recognition and the introduction of those ideals of intellectual, technical and practical training which were the ideals of Milton and of many another great mind in earlier days, but which had never before been adopted by educators and statesmen. We have at last, however, come to see that

"The type of education and training most effective in rendering the individual most helpful to his fellows is that which gives ability to be helpful. Given the power of effectively aiding others, the sympathies will be found always present; given the means of utilizing generous impulses, they will be found always fruitfully active.

"Teach habits of physical and mental activity, and a healthy body and mind will be prolific of wholesome and noble thought; cultivate skill in fruitful industries, and the inclination to employ that skill in helpful ways will not be lacking; feed the soul with the harvests of thought of all ages, with the gleanings of the wisdom of the centuries—in whatever language, however given verbal expression—and all sympathies, latent or active, will find their destined place and work. Breed 'the soul of the sage in the body of the athlete,' and give the perfected soul, within its perfected body, ability to do for itself and others what life may demand of it, and trust that what may be done most effectively for the world will be done best by this perfected humanity, through the exercise of broadest sympathies and most efficient powers of aiding fellow men.

"It is thus that the Miltonian training, reinforced by Miltonian learning, perfected by Miltonian culture, doing most for the humblest, much for the highest, whether ranked by place or by mind, giving health to the body, skill to eye and hand, stimulus to the intellect, and greatness to the soul, will, always and everywhere, most effectively broaden the sympathies and render the individual most helpful to his fellow men." *

With such education of the people, a nation is assured of permanence and progress. Demagoguism may still poison its legislatures; hysteria may continue to affect its press and here and there a community; amateurism is likely to reduce for a time the efficiency of its public services; but its youth, growing up with a true Miltonian training, with not only learning, but wisdom, not only culture, but directly practical training,

* Miltonian Teaching: an address delivered at Pratt Institute, Brooklyn, December 11, 1894.—R. H. T.

will steadily improve governmental, industrial and educational methods and raise the nation to higher than Platonian levels.

Thus, the Progress and Tendency of Mechanical Engineering have been like that of human life, in many ways. As the outcome of an evolution extending back into an infinite, or at least indefinite, past, its birth, the first sensible evidence of existence, occurred a century ago. Its growth involved the development of many and different phenomena, the perfection of all, in the adult, depending ultimately upon the perfection of each in the process of development. This mighty giant of modern civilization was conceived in liberty, nourished by law. Invention and protecting legislation, assuring to every man the fruit of his brain as of his hand, gave the child health and early and sturdy development. The introduction of new and great inventions in the early part of the century; the formulation in legal terms of our Constitution, of the patent-law and of a system of universal common-school education; the systematization of manufactures, and their care and support, until the advantages of foreign competitors were neutralized; the substitution in all departments of production of automatic and of labor-assisting machinery; the reduction of all productive vocations to scientific departments of mechanical engineering; legal provision for the coöperation of individuals, the invention of the corporation, the later coöperation of corporations in reduction of non-productive labor and the resultant decrease of costs and prices; the introduction of science and of practically applied science into the curriculum of the schools and colleges; the provision of technical and professional schools for the constructive arts and professions; the gravitation of the management of the productive, and of all industrial, operations into the hands of scientifically and practically expert men, who supplement the learning of schools by the perhaps higher learning of the arts and of the professions—all these have illustrated the progress and tendency of mechanical engineering during the nineteenth century and the plainly distinguishable tendency of the time points the way in which the twentieth century is to further illustrate this progress and tendency, in even more marked degree.

In the future, as in the recent past, the progress of invention and of the mechanic arts will undoubtedly be still onward and upward, with a still accelerated motion; the discoveries of the century may be expected to be more important and more imposing than ever before; the work of the world will be performed with a more complete system, and industrial operations of every sort will be carried on on a still larger scale. The now familiar motors, developing the energies of Nature and supplying the power needed to do the work of the world, will be, undoubtedly, still further improved and developed, and it may be hoped, if not fairly expected, that a new method of utilizing the latent powers

of Nature may be discovered, and the requisite mechanism invented, by which to evade the inevitable loss of the larger part of that energy when developed by our present thermo-dynamic machines, and thus to secure the greater part as actually utilized, as useful power. The perfection of our machinery by improvement of details by our later inventors and the production of new and still more wonderfully productive machines, automatic and labor-multiplying, will as certainly continue, and in some fields is likely to astonish us, callous as we have become to these marvels, quite as much as were our parents surprised by the inventions of the last generations. Coöperation of labor, of capital, of manufacturing organizations, will necessarily go on, and the 'captains of industry' will have continually larger and larger armies and greater and greater tasks, and we shall have generals, as well as colonels and captains and subordinates, in the vast armies of united workers of the coming century.

We shall secure a liberal supply of this world's good things by a reasonable day's labor on the part of the humblest, wealth in abundance in repayment for superior talent, industry and forethought, and comfort and a healthful and wholesome life, a happy life, will be assured to all who choose to make the most and best of opportunity, including the wealthy, whose opportunities will be readily found in the promotion of higher learning, of nobler charities and of more generous care of the physically and intellectually lame and halt and blind. We shall increase the speed of our fast trains, cross the Atlantic in less time, transport the food and clothing and wealth of the world more cheaply, and very possibly add to the fields of invention and the practically available means of transportation the long-looked-for department of aëronautics and aërodromics. We have conquered the land and the water; who shall say that Man is less equal than albatross or sparrow to the task of subduing the elements of the atmospheric world?

With further evolution in these departments, and consequent improvement in the condition of the people, all intellectual and moral conditions may be hopefully expected to improve, and the people will grow in character as they acquire knowledge, gaining intelligence as they secure ease of life, and will rise to a higher plane of rectitude and happiness as they are relieved of the grinding pressure of the poverty of earlier times.

Progress has come to be enormously rapid, and the advance of a generation is much greater than was formerly that of centuries. We may reasonably hope to see something of this multiplied progress of the coming generation; our children will see the still larger multiplication of gain of the twentieth century, and help carry the world a long way toward that ideal which has been but feebly described in Plato's Republic and More's Utopia, and has been the aspiration of all good men.

THE PERIODIC LAW.

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BEFORE the time of Lavoisier ideas concerning the nature of matter were mere speculations. Following the introduction, at the close of the eighteenth century, of the conception of the indestructibility of matter, and more especially with the introduction of the atomic theory a decade or so later, the idea of some sixty or seventy absolutely different kinds of matter received general acceptance. The unity of these different elements was, indeed, held by some, but as a pure speculation, while the evidence was all against it. It remained for the Periodic Law to show that there is a connection between these different elements. It is true, we are as far as ever from any knowledge of what that connection is, or from any knowledge of the nature of that primal substance out of which all matter is shaped, unless, indeed, the recent work of J. J. Thomson and others on the electric condition of gases is pointing us thitherward.

The early attempts to classify substances from a chemical, or rather alchemistical standpoint, were wholly superficial. Pliny, for example, describes two forms of lead, *plumbum nigrum* and *plumbum candidum*. The former term was used for lead proper, the latter for tin, though these two metals have little resemblance, except in their low melting points. Sulfuric acid was classed with the oils, as oil of vitriol, and the name has popularly and technically remained to the present, although the only resemblance of sulfuric acid to an oil is in its appearance. The chlorids of antimony and of tin were known respectively as butter of antimony and butter of tin, from the fact that they are semi-solid substances, of much the same consistency as butter from milk. Even to-day we speak familiarly of milk of lime and milk of sulfur, though but for the fact that they are whitish liquids, they have nothing in common with the product from the cow. Perhaps to us one of the most remarkable instances of classification was the association of the black oxid of manganese with the white oxid of magnesium, commonly known as calcined magnesia. The only property common to these two, *magnesia nigra* and *magnesia alba*, as they were early called, is that both are fine powders. In the seventeenth and eighteenth centuries the discovery of the different gases began, and to the workers of that day all were but different kinds of air. Thus we find 'inflammable air' as the name for hydrogen, 'fixed air' for carbonic acid gas, and 'dephlogisticated marine acid air' for chlorin. That no better principle of

classification of substances from a chemical standpoint than that of superficial outward appearance was demanded is not strange, when we recollect that at this period and, indeed, down to the close of the eighteenth century, the transmutation of metals was a popular belief of the common people and was not disproved by the chemist. There was no underlying, unchangeable principle at the basis of the different substances with which the chemist had to deal.

Lavoisier—government medallist at twenty-one, adjunct member of the French Academy at twenty-five, chemist, geologist, mineralogist and mathematician, man of business and amasser of wealth, financier, reformer, fermier général, imprisoned by Robespierre on the trumped-up charge of having adulterated tobacco with water, guillotined in 1794, when only just past fifty years old—this is the man whom the French, with much justice, call the 'Father of Chemistry,' the man who made chemistry possible as a science by furnishing it with a foundation, the doctrine of the indestructibility of matter. This he accomplished by the use of the balance. A familiar experiment had often been used to support the old idea of transmutation. When water has been boiled for a long time in a glass vessel, on evaporating the water an earthy residue is obtained, and this, said the chemists of that day, is conclusive evidence that water can be transmuted into earth by boiling; and, if water into earth, why not other substances; and why not, if we only knew the method, even the base metals into gold? When less than thirty years old, Lavoisier repeated this experiment, but he took the precaution of weighing his glass vessel with its contained water. After a hundred days' boiling, he found that there was no change in weight. On then evaporating the water he found, indeed, an earthy residue, but the glass vessel had lost an amount exactly equal in weight to that recovered from the water. In other words, the water, so far from being changed into earth, had merely dissolved out a small portion of the glass container. This and many other similar experiments the keen-witted Frenchman used to prove the indestructibility of matter, and on this fundamental doctrine the superstructure of scientific chemistry began to rise.

With this doctrine established, it became possible to consider the nature of matter from a new standpoint, and to define with some accuracy a chemical element. Back in the days of Greek philosophers, elements were very variously conceived of. To Pherekides earth was the primal element; to Anaximenes, air; to Herakleitos, fire; while Thales found in water the first principle of all things, and the followers of the Milesian philosopher were not a few for more than two millenniums. Empedokles accepted all four of these elements, and to them Aristotle added a fifth, ether, the quintessence, subtler and more divine than the other four. With these the alchemists placed a number of

substances, approaching somewhat our present idea of elements, but even down to Lavoisier's time the old Greek conceptions were not abandoned. Lavoisier's definition of an element deserves to be quoted, since more than a century of chemical progress has failed to improve or in any essential way change it. "An element," says he, in his 'Traité de Chimie,' "is a substance from which no simpler body has as yet been obtained; a body in which no change causes a diminution of weight. Every substance is to be regarded as an element until it is proved to be otherwise." With his conception of an element, Lavoisier introduced a new and scientific nomenclature into chemistry, which is to a very considerable extent in use to-day. The views of Lavoisier did not gain immediate recognition, but a decade after his untimely death the new ideas had been very generally adopted.

With the opening of a new century came the rehabilitation of a theory which had originated back in the misty days of early Greek philosophy, but which was now to be given a new value, because no longer a vague guess, but founded upon experimental evidence. This was the theory of the atomic constitution of matter. According to the Greek conception, if matter were divided into smaller and ever smaller portions, at last a point would be reached where the particles are indivisible, and such particles are the atoms. Dalton seems first to have hazarded the idea of atoms, almost as a speculation, to account (wrongly) for the various different degrees of solubility of different gases in water, and at this early stage he published a table of familiar substances, with the atomic weight of each. A decided confirmation was given to this guess by Dalton's discovery that when different gases combine, it is always in proportions expressed by whole numbers. This could most readily be explained by the theory that these gases were made up of indivisible particles called atoms, whose union conditioned the proportion between the uniting masses of gases. This atomic theory was somewhat combated by a few chemists, even Sir Humphry Davy and Mr. Wollaston for a brief time opposing it. It soon, however, made its way, and its general principles have been received by all chemists; for nearly a century it has dominated, or rather has been the foundation of, chemical theory.

According to this theory, all matter is composed of some seventy different kinds of atoms, each possessed of independent and permanent properties. Lists of the atomic weights of the commoner elements were rapidly published, the most notable being that of Berzelius, in 1815.

The fact of so many different kinds of ultimate particles of matter was naturally a great blow to those who believed in its unity. Very early there was speculation as to whether any connection existed between the different kinds of atoms. The first step in this direction was what is known as Prout's hypothesis, which was first enunciated

in 1815, with no author's signature, in Thomson's 'Annals of Philosophy.' Prout had noticed that the atomic weights of many of the lighter elements seemed to be exact multiples of that of hydrogen; hence he made the suggestion that all the different atoms may be merely aggregations of the simple hydrogen atom, and that this hydrogen atom is really the primitive element from which all other substances are made.

This was the first attempt to determine a relation between the apparently different kinds of matter, and it was more than eighty years before the advocates of the theory were finally forced to abandon it. There have been few laws in chemistry, and certainly no false hypotheses, which have given rise to so much investigation as that which has been occasioned by Prout's hypothesis. That it could have so long retained adherents among chemists, many of them men of great prominence, is due to the fact that it seems on its face to be true. When it was first published, a very considerable number of the atomic weights were approximately multiples of the weight of the hydrogen atom, far more than could be accounted for by chance. It seemed reasonable to believe that, with the meager facilities for accurate work at that day, the atoms of the few other elements would prove, when they should be accurately determined, to be also exact multiples of the hydrogen atom. This view was held by many chemists until a Belgian chemist, Jean Servais Stas, undertook to determine the atomic weight of a few of the elements with an accuracy far greater than had been known up to that time. Prout's hypothesis had been sustained by rounding off the decimals to whole numbers; Stas, before he began this work an earnest believer in the hypothesis, endeavored to determine at least one place of decimals so accurately that it could not hereafter be neglected, and his work is one of the classics of chemistry. He proved clearly that the atoms of several elements, at least, could not be multiples of that of hydrogen. Some of the supporters of the hypothesis then assumed that it was not the hydrogen atom, but a half of it, or some other fraction, which is the original matter, from which all other atoms are derived. The hypothesis may be said to have finally ended its long career when Professor Morley, of Adelbert College, showed that there is no simple ratio between the atomic weights of oxygen and hydrogen; that, instead of being 16:1, it is 15.879:1. For accuracy Professor Morley's work may be justly compared with that of Stas, but in conception of experiment and in difficulty of execution it far surpasses that of the Belgian chemist.

But while it may be considered as absolutely proved that a large share of the atoms have weights which are *not* exact multiples of that of hydrogen, yet it remains true that many of those which have been determined with the greatest degree of certainty do approach with

wonderful closeness to exact multiples. This is shown by the following table, taken from the report of the Committee on Atomic Weights of the American Chemical Society for 1899:

Arsenic	75.0	Lead	206.92	Phosphorus	31.0
Boron	11.0	Lithium	7.03	Rhodium	103.0
Bromin	79.95	Manganese	55.0	Silver	107.92
Carbon	12.0	Mercury	200.0	Sodium	23.05
Cerium	139.0	Nitrogen	14.04	Sulfur	32.07
Cobalt	59.00	Osmium	191.0	Tin	119.0
Gallium	70.0	Oxygen	16.00	Yttrium	89.0
Iron	56.0	Palladium	107.0		

In addition to these at least nine others have atomic weights differing not more than 0.1 from whole numbers. By the law of probabilities this close approach to whole numbers cannot be the result of chance, but no satisfactory explanation has as yet been offered.

Prout's hypothesis was not unique in concerning itself with an effort to show a unity of matter. Very early there was noticed a connection between the atomic weights and the properties of certain groups of elements. Attention was first called to this by Professor Döbereiner, of Jena, and an account was given of it in print in 1816, just after the first enunciation of Prout's hypothesis. Döbereiner noticed that the equivalent weight of strontium was 50, while the values then accepted for calcium and barium were respectively 27.5 and 72.5. Fifty is the mean of 27.5 and 72.5, and the properties of strontium may be looked upon as being an average of those of calcium and barium. It was soon clear, however, that strontium was as much entitled to recognition as an element as calcium or barium. Hence it appeared that there was a numerical relation between the weights of the atoms of these three elements, barium, strontium and calcium, which corresponded to both the chemical and the physical properties of the elements. Several other similar groups of three were discovered by Döbereiner, and this, which was really the earliest germ of the Periodic Law, became known as Döbereiner's law of triads. It is of especial interest, as having enabled its author to predict the atomic weight of bromin, which was later confirmed by experimental investigation. In this respect it anticipated the Periodic Law, and may be said to represent a phase of this later and greater generalization.

Little attention was attracted by the speculations of Döbereiner, and a quarter of a century or so later the subject was taken up anew by the great French chemist, Dumas. He developed to some extent the law of triads, though he made little actual advance beyond the point attained by Döbereiner. Dumas's work was, however, widely noticed, and proved very stimulating to the chemists of his day. It

is interesting to read the comments of Faraday: "This circumstance (the numerical relations between chlorin, bromin and iodin) has been made the basis of some beautiful speculations by M. Dumas, speculations which have scarcely yet assumed the consistence of a theory, and which are at the present time to be ranged among the poetic day-dreams of a philosopher; to be regarded as some of the poetic illuminations of the mental horizon, which possibly may be the harbinger of a new law. . . . We seem here to have the dawning of a new light, indicative of the mutual convertibility of certain groups of elements, although under conditions which as yet are hidden from our scrutiny." In the succeeding decade we find many chemists speculating in a similar way upon the connection which seemed to subsist between the different elements.

The two chemists whose names are associated with the dawn of the Periodic Law are De Chancourtois and Newlands. De Chancourtois arranged the elements in the order of their atomic weights in a helix inscribed upon a vertical cylinder; this he called a 'telluric screw,' and although there were many inaccuracies, as a whole it approached a form in which the Periodic Law is to-day sometimes represented. The ideas of De Chancourtois were by no means free from considerable haze, as, for example, when he states that 'the properties of bodies are the properties of numbers.' This may well be interpreted in the light of the Periodic Law, which affirms that the properties of elements are functions of their atomic weights. Even the important idea of periodicity is not overlooked by De Chancourtois, but the speculations of this ingenious French engineer and geologist had practically no effect upon the chemical thought of that day; indeed, his articles were almost unnoticed and were resurrected only after they had slumbered for nearly thirty years in obscurity.

Somewhat otherwise was it with the work of Newlands, which began to appear in 1863, just a year later than that of his French contemporary. His work was, however, wholly independent of that of De Chancourtois. His first paper was chiefly concerned with the development of numerical relations between the atomic weights, following out the ideas early expressed in Döbereiner's triads. He enlarged this so as to include more than three elements in a group. For example, not only was sodium the middle member, with mean properties, of the triad, lithium, sodium, potassium; but rubidium also belonged to this group, because two of potassium plus one of lithium gives the atomic weight of rubidium. A year later he announced his law of octaves, which is generally looked upon as a forerunner of the Periodic Law. Here he arranged the elements in the order of their atomic weights and showed that "elements having consecutive numbers frequently either belong to the same group or occupy similar positions in different

groups." "The difference between the number of the lowest member of a group and that immediately above it is seven; in other words, the eighth element starting from a given one, is a kind of repetition of the first, like the eighth note of an octave in music." While this regularity appeared in the case of the elements of low atomic weight, it failed when applied to many of those elements which have a higher weight, and also in the case of iron, cobalt and nickel. These three metals seem to break in upon the octaves, and must be left out of account before the law of octaves can be used. This irregularity Newlands noticed, enunciating his law in the words: "The numbers of analogous elements, *when not consecutive*, differ by seven, or by some multiple of seven." By 'number' he means merely the number of the element when all are arranged in a series in the order of their atomic weight. There was thus here, as in the work of De Chancourtois, the vision of a certain periodicity in the actual arrangement of the elements, and the recognition of the fact that in some way there is a connection between the properties of an element and its atomic weight. But there seemed to be no suspicion that all the properties of an element are a function, much less that they are a periodic function of its atomic weight.

It may seem strange to us that the work of these two pioneers should have been received with almost complete indifference by chemists. This results in part, at least, as has been pointed out by Mendeléeff, from the too-limited application of Newlands's law. Relations were brought out between little groups of elements, like Döbereiner's triads, but comparisons were not made between dissimilar elements, and even the groups made up by taking the seventh elements often contained those which were far from being similar in their properties. Thus we find the first, and hence analogous, elements of his eight octaves as follows: Hydrogen, fluorin, chlorin, cobalt-nickel, bromin, palladium, tellurium, platinum-iridium. Such a grouping as this could hardly be expected to appeal strongly to chemists, especially as iodin, an element which obviously belongs with fluorin, chlorin and bromin, is relegated to the seventh group of elements. The lack of enthusiasm on the part of chemists at the reception of Newlands's work may be judged from an incident. When his paper was read at the meeting of the Chemical Society, one of the members present asked of Professor Newlands whether he had ever tried arranging the elements according to the order of their initial letters.

The Periodic Law in its present form was first enunciated by Professor Dmitri Mendeléeff, in 1869, in a paper read before the Russian Physico-Chemical Society. It is true that five years earlier Lothair Meyer had published in the first edition of his 'Modern Theory of Chemistry' a list of the elements arranged according to atomic weights,

somewhat after the method of Newlands, but this table could be considered in no sense an advance upon the table of his English contemporary. It was not so much a periodic table as a summary of the grouping of the elements in more or less natural groups. Meyer, indeed, made his earlier table the basis of his later work, but these subsequent amendments to the table were made after the publication of Mendeléeff's first table and show clearly the influence of his work.

In his first paper, Mendeléeff gives several different arrangements of the elements, all, however, embodying the same principles. The principal table, of which the others are variants, shows many errors and crudities, but the underlying principles of the Periodic Law, as to-day recognized, are clearly apparent. This table is as follows:

MENDELÉEFF'S FIRST TABLE. 1869.

			Ti 50	Zr.... 90	? 180	
			V.....51	Nb... 94	Ta ...182	
			Cr 52	Mo .. 96	W 186	
			Mn.....55	Rh...104.4	Pt....197.4	
			Fe 56	Ru ..104.4	Ir....198	
			Ni, Co..59	Pd...106.6	Os....199	
H.....1			Cu.....63.4	Ag...108	Hg.. 200	
	Be.... 9.4	Mg ...24	Zn.....65.2	Cd...112		
	B.....11	Al.....27.4	? 68	Ur...116	Au ..197	
	C.....12	Si.....28	? 70	Sn ...118		
	N.....14	P.....31	As..... 75	Sb...122	Bi....210	
	O.....16	S.....32	Se 79.4	Te....128 ?		
	F.....19	Cl....35.5	Br.....80	I.....127		
	Na.....23	K.....39	Rb.....85.4	Cs...133	Tl....204	
		Ca....40	Sr.....87.6	Ba...137	Pb...207	
		? 45	Ce 92			
		? Er ..56	La 94			
		? Y ..60	Di.....95			
		? In...75.6	Th.....118			

The resemblance to the modern tables comes out yet more strongly when we examine Mendeléeff's horizontal table, which was published in the same paper, and in which the doubtful elements and those whose position was not clear were omitted:

MENDELÉEFF'S HORIZONTAL TABLE. 1868.

Li	Na	K	Cu	Rb	Ag	Cs	..	Tl
Be	Mg	Ca	Zn	Sr	Cd	Ba	..	Pb
B	Al	..	..	..	Ur	..	..	B
C	Si	Ti	..	Zr	Sn	..	..	..
N	P	V	As	Nb	Sb	..	Ta	..
O	S	..	Se	..	Te	..	W	..
F	Cl	..	Br	..	I	..	..	..

In the first table the elements are arranged in vertical columns, in the order of their atomic weights. They fall in a way into groups of seven, as in Newlands's octaves, but after the first two octaves there

are quite a number of elements before the next group of seven is reached, and the same is true in each succeeding column. The next year, 1870, Meyer published a table in which he brought these outside elements into something of order by pointing out the existence of a double periodicity after the first two octaves have been passed, and showing that the alternate periods resemble each other closely. This was brought out with greater clearness in the revised table which Mendeléeff published in 1871. The skill of the author of this table is apparent when we consider that it is, with few additions, the generally accepted table in use at the present day. This table, which is given on the following page, when compared with that of two years before, shows how great had been the development.

One well-recognized test of the truth of any theory is its use in prediction. In this table Mendeléeff did not hesitate to make certain changes in the generally received atomic weights, in order to bring facts into conformity with his table. His was not the position of the ancient philosopher who would have all phenomena bend to his preconceived theory, and if the facts failed to yield, so much the worse for the facts. Mendeléeff had confidence that this Periodic Law was the expression of a great truth of nature, and so firm was his confidence that he could not but believe that when the phenomena did not agree, it was from imperfect observation and interpretation of the facts. A good instance of this is seen in the case of the metals of the platinum group. As far as observation had gone, osmium had the largest atomic weight of these metals, followed by iridium and platinum, of equal weight, and all these metals were lighter than gold. According to the Periodic Law the reverse should be the case. Mendeléeff affirmed that the discrepancy in this case was probably due to the fact that the atomic weights of these metals had not been determined with an accuracy commensurate with the work of the table. It is an interesting confirmation that some years later, Seubert took up this atomic weight problem, and found that the views of Mendeléeff were correct. Gold has the highest atomic weight of these elements, platinum the next highest, iridium follows and osmium comes lowest of all, its previously determined weight having been seven or eight units too high.

Along the line of predictions a still more remarkable use of the table appeared in connection with the vacant spaces. There were many places in the table where elements might be expected, which were, however, then unknown. Could the table stand the test of actually predicting the existence of an unknown element? Mendeléeff did not think this too great a strain to put upon his work, and he ventured not merely to predict that elements might be expected with atomic weights of 44, 68 and 72, but he was even bold enough to describe these elements under the names of eka-boron, eka-aluminum and eka-

MENDELEEFF'S TABLE OF 1871.

Series.	Group I. R_2O.	Group II. RO.	Group III. R_2O_3.	Group IV. RH_4. RO_2.	Group V. RH_3. R_2O_5.	Group VI. RH_2. RO_3.	Group VII. R H. R_2O_7.	Group VIII. RO_4.
1.....	H=1							
2.....	Li=7	Be=9.4	B=11	C=12	N=14	O=16	F=19	
3.....	Na=23	Mg=24	Al=27.3	Si=28	P=31	S=32	Cl=35.5	
4.....	K=39	Ca=40	— =44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59 Ni=59, Cu=63
5.....	(Cu=63)	Zn=65	— = 68	— = 72	As=75	Se=78	Br=80	
6.....	Rb=85	Sr=87	? Y=88	Zr=90	Nb=94	Mo=96	— = 100	Ru=104, Pd=104 Pd=106, Ag=108
7.....	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	I=127	
8.....	Cs=133	Ba=137	? Di=138	? Ce=140	.....	.....	.....	.....
9.....	.....	.....	.....	.....	.....	.....	.....	....
10.....	.....	.....	? Er=178	? La=180	Ta=182	W=134	.....	Os=195, Ir=197 Pt=198, Au=199
11.....	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	.....	.....	
12.....	.....	.....	.....	Th=231	.....	U=240	.....	.....

silicon, in several cases going into considerable detail as to the properties of the elements and their compounds. It was in 1875 that the first of these predictions was fulfilled in the discovery of gallium by Lecoq de Boisbaudran. This metal fell in the place which Mendeléeff had given to eka-aluminum, and its specific gravity is 5.9, while 5.8 was the figure which had been foretold. Four years later Nilson discovered eka-boron, and gave to it the name scandium. In 1885 a new silver mineral, argyrodite, was found in the Freiberg mines, and every analysis made of it showed a discrepancy of six or seven per cent. This soon led to the recognition by the analyst, Clemens Winkler, of the presence of a new element, and it further appeared that this new element was Mendeléeff's eka-silicon. Not to be outdone by the French and Swedish chemists, Winkler patriotically called the new metal germanium. It is worth while to show side by side, a few of the predictions of the properties of eka-silicon, published by Mendeléeff in 1872, and the actual properties of germanium, as experimentally determined by Winkler in 1886:

Eka-Silicon. Symbol, Es.	Germanium. Symbol, Ge.
ELEMENT.	
Atomic weight, 72.	Atomic weight, 72.3.
Specific gravity, 5.5.	Specific gravity, 5.469 at 20°.
OXID.	
Formula, EsO_2.	Formula, GeO_2.
Specific gravity, 4.7.	Specific gravity, 4.703 at 18°.
CHLORID.	
Formula, $EsCl_4$.	Formula, $GeCl_4$.
Liquid, boiling a little below 100°.	Liquid, boiling at 86°.
Specific gravity, 1.9 at 0°.	Specific gravity, 1.887 at 18°.
METALLO-ORGANIC COMPOUND.	
Formula, Es $(C_2H_5)_4$.	Formula, Ge $(C_2H_5)_4$.
Liquid, boiling point, 160°.	Liquid, boiling point, 160°.
Specific gravity, 0.96.	Specific gravity, slightly less than water (which is 1.0).

So close is this agreement that it is difficult to realize that Mendeléeff's forecasts were put in print more than a decade before the element had ever been handled by man.

Since the corrected form of Mendeléeff's table was published in 1871, there has been no end to the speculation upon the subject, and dozens of tables, emphasizing different relations of the elements, have been proposed. Few of these have equaled that of the Russian chemist in simplicity or have as few obscure points. One of these tables, suggested a few years ago by Dr. F. P. Venable, of the University of North Carolina, may be noticed as presenting some decided advantages over that of Mendeléeff:

VENABLE'S TABLE. 1895. (SLIGHTLY MODIFIED.)

H																He?	
Li		Gl		B		C		N		O		F				Ne?	
Na		Mg		Al		Si		P		S		Cl				Ar?	
K	Cu	Ca	Zn	Sc	Ga	Ti	Ge	V	As	Cr	Se	Mn	Br	Fe	Co	Ni	
Rb	Ag	Sr	Cd	Y	In	Zr	Sn	Cb	Sb	Mo	Te	▬	I	Ru	Rh	Pd	
Cs	†	Ba	†	La	†	Ce	†	*	†	*	†	*	†	*	*	*	
*	Au	*	Hg	*	Tl	*	Pb	Ta	Bi	W	†	*	†	Os	Ir	Pt	
*		*		*		Th		*		U							

* † Possible elements, now unknown. ▬ Eka-Manganese.

Most tables present a difficulty in that they place sodium in the group or sub-group with copper, silver and gold, while it would most naturally fall in the group with lithium, potassium, rubidium and cesium. So magnesium would be placed according to its properties, not so closely with zinc and cadmium, as with glucinum, calcium, strontium and barium. Fluorin belongs rather with chlorin, bromin and iodin than with manganese, the metal with which it is associated in most tables. So oxygen belongs with sulfur, selenium and tellurium, rather than with chromium and molybdenum. This is remedied in Venable's table. The first element in any group the author calls the group element or bridge element; for it often possesses properties which ally it to the elements of the next groups. The second element he calls the type element, and in this is, as it were, shadowed forth the character of the succeeding elements of the same group. From this point on, the group is divided into two series, one more and the other less electro-positive or negative, as the case may be. The first three groups are for the most part made up of electro-positive elements, while those of the fifth, sixth and seventh groups are relatively electro-negative. Now in the former the elements of the more positive series resemble the type element of their group more strongly than those of the less positive series. In the relatively negative fifth, sixth and seventh groups, the reverse is the case. This grouping thus places sodium with potassium and chlorin with bromin. In the fourth group,

which lies between the extremes, the type element, silicon, foreshadows the members of its two series to an approximately equal extent.

As the tables which graphically portray the Periodic Law stand to-day, there is much which still remains to be cleared up. At the very outset we are met by the fact that we cannot tell in which group as familiar an element as hydrogen ought to be placed. It generally receives the first place in group one, but to some extent at least this position is based upon a misapprehension. Some years ago Pictet, of Geneva, was engaged in that work on the condensation and liquefaction of gases, which has rendered his name famous. On compressing hydrogen at a very low temperature, he obtained, on suddenly reducing the pressure, some heavy, steel-blue drops, much resembling mercury. This was erroneously supposed to be hydrogen in the liquid form. As a result, it seemed only natural to classify hydrogen with the metallic elements of the first group. Not only have later investigations shown that these drops were not liquid hydrogen, but quite recently Dewar has actually obtained this substance, which proves to be a colorless, limpid liquid, with the extraordinarily low specific gravity of about 0.07. As far then as physical properties go, there is no justification in classifying hydrogen with the metals of group one. Chemically, however, hydrogen is like the metals, electro-positive, though very weakly so, and it is possible that its position in the first group is less awkward than would be any other.

Of the other elements in the table with atomic weight below 100, all seem fairly well placed, though we have not as much knowledge of scandium as we could wish, and there is a difficulty that we shall soon notice in the eighth group. The first apparent blank space in the table is for an element with atomic weight of about 100. Such an element would be known as eka-manganese, and would possess properties which would to a considerable extent resemble those of manganese, but perhaps more closely those of ruthenium. Beyond this in the table we find many gaps, partly from the inadequacy of our chemical knowledge and partly from the likelihood that there exist rare elements which have not yet been discovered. Such elements probably occur in extremely small quantities, and may, for many years, perhaps forever, elude chemists. It seems improbable that there are undiscovered elements which exist in more than very small quantities; this is the testimony, not only of the chemical laboratory, but also of the spectroscope, that instrument which reveals to us the composition, not merely of substances in the laboratory, but also that of the sun and of the distant stars. From barium to tantalum few elements are known to which a definite place can be assigned, but here there is an indefinitely large number of what Crookes has called meta-elements, the rare earths. Their rela-

tion to the table is as yet hardly more than speculative, and they have been likened to the asteroids of the solar system.

From tantalum to bismuth the table is very regular, except that the element of the manganese series, which would have an atomic weight of about 188, is unknown, as we have already seen is the case with ekamanganese. Above bismuth, with its weight of 208, we know but two elements, thorium, 231, and uranium, 240. Since the discovery of the Röntgen rays, great interest has been excited by different kinds of rays which, though they may not be visible to the naked eye, are nevertheless capable of affecting the photographic plate. The only elements, as far as yet known, which yield such rays are these two of extraordinarily high atomic weight, thorium and uranium. Closely connected with this phenomenon is that of giving off luminous rays when not exposed to light. It has recently been discovered that while uranium can give off comparatively feeble rays, there is contained in the principal uranium mineral, pitchblende, matter which is much more active than uranium. Further investigation seems to show that there are at least three such substances present in pitchblende; which have been named radium (from the rays it gives off), polonium (from its discoverer's native land), and actinium (from its ratio-activity). Of these radium alone has been studied at all extensively, and even its claim to be called a chemical element is by no means established. It strongly resembles barium, but it gives off rays easily visible in the dark, continuing to shine indefinitely. There is much doubt as to whether it be not really a peculiar form of barium, but recent determinations of its atomic weight, in a condition only partially purified, indicate that it has a higher atomic weight than barium, and that it may in this respect resemble thorium and uranium.

It may seem rather remarkable that, inasmuch as Döbereiner had brought out the resemblances between elements of the same group in his triads, nearly half a century should have elapsed before the essential features of the Periodic Law were discovered. This is due, chiefly at least, to three causes. First, there would have been many more gaps in the table then than now, so many new elements having been discovered since that day; second, the atomic weights of the elements were then so imperfectly known that, using the weights then accepted, it is impossible to construct a periodic table; the third great difficulty lay in the fact that nine very important elements refused to be reduced to order, and finally were excluded and relegated to an outlying group of unique properties. These nine elements are iron, cobalt, nickel and the so-called platinum metals, platinum, palladium, iridium, rhodium, osmium and ruthenium. As a matter of fact, these nine metals cannot be brought into any of the seven regular groups, but must be placed by themselves in a single group of three series, or in three groups. This

eighth group proves to be transitional between group seven and group one; iron, cobalt and nickel make a direct gradation from manganese to copper; ruthenium, rhodium and palladium, from molybdenum to silver; osmium, iridium and platinum, from tungsten to gold. Not only do these three triplets stand between these other elements in atomic weight, but their properties also show a similar gradation.

While now we have these transitional elements, the question might very naturally arise whether there are similar transitional elements from fluorin to sodium and from chlorin to potassium. The case here is, however, somewhat different from the former one. Manganese and copper are both metals, and not so widely separated in properties; the transitional elements, iron, cobalt and nickel, partake of the nature of both extremes, and the transition seems a natural one. Hardly any elements can be more unlike than fluorin and sodium, or chlorin and potassium. Chlorin is very electro-negative, potassium as strongly electro-positive. A transitional element would thus probably be inert, that is, lacking in both electro-positiveness and in electro-negativeness, and up to a few years ago such an element could hardly have been conceived of. At that time Lord Rayleigh was engaged in determining with all possible accuracy the density of nitrogen. In this work he prepared nitrogen by several different methods. Some specimens were obtained by the decomposition of chemical compounds, such as urea and ammonium nitrite, others from the air by removing the oxygen. To his surprise, Lord Rayleigh found that in every case the nitrogen obtained from the atmosphere was slightly heavier than that prepared from chemical compounds. In searching for the cause of this difference, Lord Rayleigh and Professor Ramsay, who had been associated with him in this work, found that there is present in the atmosphere a new gas, much like nitrogen in its properties, whose existence, although it is present to the extent of nearly one per cent, had been unsuspected. This gas, christened argon from its inertness, is nearly three times as heavy as nitrogen, and it is this that increases the weight of atmospheric nitrogen slightly above the weight of pure nitrogen, obtained from chemical compounds. Stimulated by this discovery it was not long before Ramsay had isolated from the atmosphere at least two other gases, both characterized by an inertness similar to that of argon. These are helium, whose spectrum had long been known from the fact that this gas is plentiful in the corona of the sun, and neon. It is probable that there are several other similar gases in the atmosphere, and one, xenon, has been recently isolated by Ramsay. It is not uninteresting to note that argon had been in the hands of chemists from the time of Cavendish down, but all had supposed it to be nitrogen. Under the influence of the electric spark oxygen and nitrogen may be made to combine with each other. In Cavendish's experiment

the spark was passed through the air, which consists chiefly of a mixture of nitrogen and oxygen, and the resultant oxid of nitrogen was absorbed in caustic potash. More oxygen was added from time to time until the last of the nitrogen was used up. Now Cavendish noticed, as have many chemists since his day, that it was always impossible to remove all the nitrogen; in every case about one per cent. of gas remained. There is no record that any one ever suspected that this residue was not nitrogen; such is, however, the fact, and the gases, argon, helium and, perhaps, others are present. These can be best recognized by passing an electric spark through the rarefied gas and examining the spectrum. It seems now very strange to us that an element so abundant that an ordinary sized room contains no less than a thousand liters should have so long escaped discovery. The reason is not far to seek. Argon and its congeners are distinguished by a most remarkable exhibition of properties, in that they have apparently no chemical affinity, and no compounds of them are known. From this fact it has been argued by some that these gases cannot be considered chemical elements, for all elements hitherto known do form compounds with other elements. It is, however, a curious fact that in the periodic table we find, in the eighth group, place for several just such elements, as we have seen, without affinity, and neither positive nor negative in electrochemical character. It may well be that helium, neon, argon and xenon belong in these vacant spaces.

If this be the case, there is still a difficulty which confronts us, and this is that argon possesses an atomic weight slightly higher than the next element in order, potassium, instead of lower. This would not, however, be a unique instance of such a difficulty in the table. It was formerly thought that the two metals, nickel and cobalt, had identical atomic weights, and though the salts of nickel are generally green, and those of cobalt red, in other respects these metals and their compounds are very much alike. After the discovery of the Periodic Law, when it was seen that cobalt belonged in the second series of the eighth group and nickel in the third, it was supposed that further study would necessarily show nickel to have an appreciably higher atomic weight than cobalt. We have already seen that in this same group, before the appearance of the periodic table, the accepted atomic weights of osmium, iridium and platinum were incorrect, and it was the fact of their mis-arrangement in the table which caused Seubert to revise their weights. Very much labor has been spent upon the revision of the atomic weights of nickel and cobalt. Gerhardt Krüss supposed he had found a new and heavier metal, hitherto unknown, in ordinary cobalt, and that this caused the atomic weight to be estimated too high. He called the new metal gnomium, but it was soon shown that gnomium has no real existence. The more accurate the

determinations, the more probable it seemed that in reality cobalt, and not nickel, as demanded by theory, has the greater weight. The whole subject has been very carefully investigated in the last few years by Prof. Theodore W. Richards at Harvard University, and there seems now to be no doubt but that Nature has unexpectedly and inexplicably reversed the position of these elements.

Another instance that seems to be of the same nature is that as far as the most accurate determinations go, tellurium has an atomic weight greater than that of iodin, instead of less. At present it is impossible to explain these abnormalities, but they assure us of the possibility that argon may have a higher atomic weight than potassium, and yet belong to the eighth group.

What now is the present position of the philosophy of matter from the light thrown upon it by the Periodic Law? In the first place, drawing our deduction from the marvelously accurate determinations of the relative weights of the atoms of the different elements, to which chemists have been incited by the Periodic Law, it may be considered as absolutely settled that the elements are not groups of hydrogen atoms, nor are they composed of half or quarter hydrogen atoms. As enunciated by Prout, the hypothesis which goes by his name may be considered as finally proved untenable; the atomic weights are not multiples of the weight of the hydrogen atom, nor any simple fraction thereof. But while this is the case, it is perfectly clear from the Periodic Law that the properties of an atom are a periodic function of its atomic weight. It would seem that this can be true only if the material of which all atoms are made is the same. This does not necessarily mean that there is but one kind of matter, and that all atoms are merely different quantities of this 'urstoff.' There may be several kinds of matter, and different kinds of atoms may represent varying proportions of a few constituents.

There have been many attempts to reduce the Periodic Law to mathematics, in order to find a numerical value for the function which expresses the relation between atomic weight and an element's place in the series. Such efforts have been thus far wholly unsuccessful. It is by no means impossible that such relations will be found in the future, but at present the atomic weights of comparatively few elements have been determined with great accuracy. When this work has been extended to a greater number of elements, and when the position of the rare elements and of the inert atmospheric gases has been definitely settled, we may hope for more light upon the principles underlying the Periodic Law.

At present this law occupies much the same position as two other great generalizations of natural science. The fact of gravitation was long ago discovered. The laws by which it acts are well known, and

yet the cause of gravitation is even to-day a mere speculation, and no link has yet been discovered to connect the three phases of attraction, gravitation between masses, cohesion and adhesion between molecules, and chemical affinity between atoms.[1] The fact of evolution is universally recognized, much is known and more is a matter of speculation as to how and why evolution has taken place, but why an organism tends to resemble its progenitor and why it tends to vary are as unknown as before the days of Darwin and Wallace. So the Periodic Law is, after all, a mere statement of fact. But it is a statement which has already exerted upon chemistry an influence as great as that of gravitation and evolution in their respective fields, and is destined more and more to become the very foundation of chemistry. We may hope and confidently expect that it will eventually lead us to the real constitution of matter.

A PLEA FOR PURE SCIENCE.*

BY THE LATE PROFESSOR HENRY A. ROWLAND
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THE question is sometimes asked us as to the time of year we like the best. To my mind, the spring is the most delightful; for nature then recovers from the apathy of winter, and stirs herself to renewed life. The leaves grow, and the buds open, with a suggestion of vigor delightful to behold; and we revel in this ever-renewed life of nature. But this cannot always last. The leaves reach their limit; the buds open to the full, and pass away. Then we begin to ask ourselves whether all this display has been in vain, or whether it has led to a bountiful harvest.

So this magnificent country of ours has rivalled the vigor of spring in its growth. Forests have been levelled, and cities built, and a large and powerful nation has been created on the face of the earth. We are proud of our advancement. We are proud of such cities as this, founded in a day upon a spot over which, but a few years since, the red man hunted the buffalo. But we must remember that this is only the spring of our country. Our glance must not be backward; for however beautiful leaves and blossoms are, and however marvelous their rapid increase, they are but leaves and blossoms after all. Rather should we look forward to discover what will be the outcome of all this, and what the chance of harvest. For if we do this in time, we may discover the worm which threatens the ripe fruit, or the barren spot where the harvest is withering for want of water.

I am required to address the so-called physical section of this association. Fain would I speak pleasant words to you on this subject; fain would I recount to you the progress made in this subject by my countrymen and their noble efforts to understand the order of the universe. But I go out to gather the grain ripe to the harvest, and I find only tares. Here and there a noble head of grain rises above the weeds; but so few are they, that I find the majority of my countrymen

* This address by Prof. H. A. Rowland, whose recent death all men of science deplore, was given before the Section of Physics of the American Association for the Advancement of Science in 1883. It is here republished as a tribute to his memory, demonstrating as it does his keen intellect and strong personality. While the state of American science in 1883 was scarcely as backward as might be supposed from reading this address, there has certainly been a remarkable advance in the past eighteen years. In this advance Rowland was one of the great leaders.—EDITOR.

know them not, but think that they have a waving harvest, while it is only one of weeds after all. American science* is a thing of the future, and not of the present or past; and the proper course of one in my position is to consider what must be done to create a science of physics in this country rather than to call telegraphs, electric lights and such conveniences by the name of science. I do not wish to underrate the value of all these things: the progress of the world depends on them, and he is to be honored who cultivates them successfully. So also the cook who invents a new and palatable dish for the table benefits the world to a certain degree; yet we do not dignify him by the name of a chemist. And yet it is not an uncommon thing, especially in American newspapers, to have the *applications* of science confounded with pure science; and some obscure American who steals the ideas of some great mind of the past, and enriches himself by the application of the same to domestic uses, is often lauded above the great originator of the idea, who might have worked out hundreds of such applications, had his mind possessed the necessary element of vulgarity. I have often been asked, which was the more important to the world, pure or applied science. To have the applications of a science, the science itself must exist. Should we stop its progress, and attend only to its applications, we should soon degenerate into a people like the Chinese, who have made no progress for generations, because they have been satisfied with the applications of science, and have never sought for reasons in what they have done. The reasons constitute pure science. They have known the application of gunpowder for centuries; and yet the reasons for its peculiar action, if sought in the proper manner, would have developed the science of chemistry, and even of physics, with all their numerous applications. By contenting themselves with the fact that gunpowder will explode, and seeking no farther, they have fallen behind in the progress of the world; and we now regard this oldest and most numerous of nations as only barbarians. And yet our own country is in this same state. But we have done better; for we have taken the science of the old world, and applied it to all our uses, accepting it like the rain of heaven, without asking whence it came, or even acknowledging the debt of gratitude we owe to the great and unselfish workers who have given it to us. And, like the rain of heaven, this pure science has fallen upon our country, and made it great and rich and strong.

To a civilized nation of the present day, the applications of science are a necessity; and our country has hitherto succeeded in this line, only for the reason that there are certain countries in the world where

* In using the word 'science,' I refer to physical science, as I know nothing of natural science. Probably my remarks will, however, apply to both, but I do not know.

pure science has been and is cultivated, and where the study of nature is considered a noble pursuit. But such countries are rare, and those who wish to pursue pure science in our own country must be prepared to face public opinion in a manner which requires much moral courage. They must be prepared to be looked down upon by every successful inventor whose shallow mind imagines that the only pursuit of mankind is wealth, and that he who obtains most has best succeeded in this world. Everybody can comprehend a million of money; but how few can comprehend any advance in scientific theory, especially in its more abstruse portions! And this, I believe, is one of the causes of the small number of persons who have ever devoted themselves to work of the higher order in any human pursuit. Man is a gregarious animal, and depends very much, for his happiness, on the sympathy of those around him; and it is rare to find one with the courage to pursue his own ideals in spite of his surroundings. In times past, men were more isolated than at present, and each came in contact with a fewer number of people. Hence that time constitutes the period when the great sculptures, paintings and poems were produced. Each man's mind was comparatively free to follow its own ideals, and the results were the great and unique works of the ancient masters. To-day the railroad and the telegraph, the books and newspapers, have united each individual man with the rest of the world: instead of his mind being an individual, a thing apart by itself, and unique, it has become so influenced by the outer world, and so dependent upon it, that it has lost its originality to a great extent. The man who in times past would naturally have been in the lowest depths of poverty, mentally and physically, to-day measures tape behind a counter, and with lordly air advises the naturally born genius how he may best bring his outward appearance down to a level with his own. A new idea he never had, but he can at least cover his mental nakedness with ideas imbibed from others. So the genius of the past soon perceives that his higher ideas are too high to be appreciated by the world: his mind is clipped down to the standard form; every natural offshoot upward is repressed, until the man is no higher than his fellows. Hence the world, through the abundance of its intercourse, is reduced to a level. What was formerly a grand and magnificent landscape, with mountains ascending above the clouds, and depths whose gloom we cannot now appreciate, has become serene and peaceful. The depths have been filled, and the heights levelled, and the wavy harvests and smoky factories cover the landscape.

As far as the average man is concerned, the change is for the better. The average life of man is far pleasanter, and his mental condition better than before. But we miss the vigor imparted by the mountains, We are tired of mediocrity, the curse of our country. We are tired of

seeing our artists reduced to hirelings, and imploring Congress to protect them against foreign competition. We are tired of seeing our countrymen take their science from abroad, and boast that they here convert it into wealth. We are tired of seeing our professors degrading their chairs by the pursuit of applied science instead of pure science; or sitting inactive while the whole world is open to investigation; lingering by the wayside while the problem of the universe remains unsolved. We wish for something higher and nobler in this country of mediocrity, for a mountain to relieve the landscape of its monotony. We are surrounded with mysteries, and have been created with minds to enjoy and reason to aid in the unfolding of such mysteries. Nature calls to us to study her, and our better feelings urge us in the same direction.

For generations there have been some few students of science who have esteemed the study of nature the most noble of pursuits. Some have been wealthy, and some poor; but they have all had one thing in common—the love of nature and its laws. To these few men the world owes all the progress due to applied science, and yet very few ever received any payment in this world for their labors.

Faraday, the great discoverer of the principle on which all machines for electric lighting, electric railways and the transmission of power must rest, died a poor man, although others and the whole world have been enriched by his discoveries. And such must be the fate of the followers in his footsteps for some time to come.

But there will be those in the future who will study nature from pure love, and for them higher prizes than any yet obtained are waiting. We have but yet commenced our pursuit of science, and stand upon the threshold wondering what there is within. We explain the motion of the planets by the law of gravitation; but who will explain how two bodies, millions of miles apart, tend to go toward each other with a certain force?

We now weigh and measure electricity and electric currents with as much ease as ordinary matter, yet have we made any approach to an explanation of the phenomenon of electricity? Light is an undulatory motion, and yet do we know what it is that undulates? Heat is motion, yet do we know what it is that moves? Ordinary matter is a common substance, and yet who shall fathom the mystery of its internal constitution?

There is room for all in the work, and the race has but commenced. The problems are not to be solved in a moment, but need the best work of the best minds, for an indefinite time.

Shall our country be contented to stand by, while other countries lead in the race? Shall we always grovel in the dust, and pick up the crumbs which fall from the rich man's table, considering ourselves richer than he because we have more crumbs, while we forget that he

has the cake, which is the source of all crumbs? Shall we be swine, to whom the corn and husks are of more value than the pearls? If I read, aright, the signs of the times, I think we shall not always be contented with our inferior position. From looking down we have become almost blind, but may recover. In a new country, the necessities of life must be attended to first. The curse of Adam is upon us all, and we must earn our bread.

But it is the mission of applied science to render this easier for the whole world. There is a story which I once read that will illustrate the true position of applied science in the world. A boy, more fond of reading than of work, was employed, in the early days of the steam engine, to turn the valve at every stroke. Necessity was the mother of invention in his case: his reading was disturbed by his work, and he soon discovered that he might become free from his work by so tying the valve to some movable portion of the engine, as to make it move its own valve. So I consider that the true pursuit of mankind is intellectual. The scientific study of nature in all its branches, of mathematics, of mankind in its past and present, the pursuit of art, and the cultivation of all that is great and noble in the world—these are the highest occupation of mankind. Commerce, the applications of science, the accumulation of wealth, are necessities which are a curse to those with high ideals, but a blessing to that portion of the world which has neither the ability nor the taste for higher pursuits.

As the applications of science multiply, living becomes easier, the wealth necessary for the purchase of apparatus can better be obtained, and the pursuit of other things beside the necessities of life becomes possible.

But the moral qualities must also be cultivated in proportion to the wealth of the country, before much can be done in pure science. The successful sculptor or painter naturally attains to wealth through the legitimate work of his profession. The novelist, the poet, the musician, all have wealth before them as the end of a successful career. But the scientist and the mathematician have no such incentive to work, they must earn their living by other pursuits, usually teaching, and only devote their surplus time to the true pursuit of their science. And frequently, by the small salary which they receive, by the lack of instrumental and literary facilities, by the mental atmosphere in which they exist, and, most of all, by their low ideals of life, they are led to devote their surplus time to applied science or to other means of increasing their fortune. How shall we, then, honor the few, the very few, who, in spite of all difficulties, have kept their eyes fixed on the goal, and have steadily worked for pure science, giving to the world a most precious donation, which has borne fruit in our greater knowledge of the universe and in the applications to our physical life which have

enriched thousands and benefited each one of us? There are also those who have every facility for the pursuit of science, who have an ample salary and every appliance for work, yet who devote themselves to commercial work, to testifying in courts of law, and to any other work to increase their present large income. Such men would be respectable if they gave up the name of professor, and took that of consulting chemists or physicists. And such men are needed in the community. But for a man to occupy the professor's chair in a prominent college, and, by his energy and ability in the commercial applications of his science, stand before the local community in a prominent manner, and become the newspaper exponent of his science, is a disgrace both to him and his college. It is the death-blow to science in that region. Call him by his proper name, and he becomes at once a useful member of the community. Put in his place a man who shall by precept and example cultivate his science, and how different is the result! Young men, looking forward into the world for something to do, see before them this high and noble life, and they see that there is something more honorable than the accumulation of wealth. They are thus led to devote their lives to similar pursuits, and they honor the professor who has drawn them to something higher than they might otherwise have aspired to reach.

I do not wish to be misunderstood in this matter. It is no disgrace to make money by an invention, or otherwise, or to do commercial scientific work under some circumstances. But let pure science be the aim of those in the chairs of professors, and so prominently the aim that there can be no mistake. If our aim in life is wealth, let us honestly engage in commercial pursuits, and compete with others for its possession. But if we choose a life which we consider higher, let us live up to it, taking wealth or poverty as it may chance to come to us, but letting neither turn us aside from our pursuit.

The work of teaching may absorb the energies of many; and, indeed, this is the excuse given by most for not doing any scientific work. But there is an old saying, that where there is a will there is a way. Few professors do as much teaching or lecturing as the German professors, who are also noted for their elaborate papers in the scientific journals. I myself have been burdened down with work, and know what it is; and yet I here assert that all *can* find time for scientific research if they desire it. But here, again, that curse of our country, mediocrity, is upon us. Our colleges and universities seldom call for first-class men of reputation, and I have even heard the trustee of a well-known college assert that no professor should engage in research because of the time wasted! I was glad to see, soon after, by the call of a prominent scientist to that college, that the majority of the trustees did not agree with him.

That teaching is important, goes without saying. A successful teacher is to be respected; but if he does not lead his scholars to that which is highest, is he not blameworthy? We are, then, to look to the colleges and universities of the land for most of the work in pure science which is done. Let us, therefore, examine these latter and see what the prospect is.

One, whom perhaps we may here style a practical follower of Ruskin, has stated that while in this country he was variously designated by the title of captain, colonel and professor. The story may or may not be true, but we all know enough of the customs of our countrymen not to dispute it on general principles. All men are born equal: some men are captains, colonels and professors, and, therefore, all men are such. The logic is conclusive; and the same kind of logic seems to have been applied to our schools, colleges and universities. I have before me the report of the Commissioner of Education for 1880. According to that report, there were 389,* or say, in round numbers, 400 institutions, calling themselves colleges or universities, in our country! We may well exclaim that ours is a great country, having more than the whole world beside. The fact is sufficient. The whole earth would hardly support such a number of first-class institutions. The curse of mediocrity must be upon them, to swarm in such numbers. They must be a cloud of mosquitoes, instead of eagles as they profess. And this becomes evident on further analysis. About one-third aspire to the name of university; and I note one called by that name which has two professors and eighteen students, and another having three teachers and twelve students! And these instances are not unique, for the number of small institutions and schools which call themselves universities is very great. It is difficult to decide from the statistics alone the exact standing of these institutions. The extremes are easy to manage. Who can doubt that an institution with over 800 students, and a faculty of seventy, is of a higher grade than those above cited having ten or twenty students and two or three in the faculty? Yet this is not always true; for I note one institution with over 500 students which is known to me personally as of the grade of a high school. The statistics are more or less defective, and it would much weaken the force of my remarks if I went too much into detail. I append the following tables, however, of 330 so-called colleges and universities:

218	had	from	0	to	100	students.
88	"	"	100	"	200	"
12	"	"	200	"	300	"
6	"	"	300	"	500	"
6	over		500			

* Three hundred and sixty-four reported on, and twenty-five not reported.

Of 322 so-called colleges and universities:

206 had 0 to 10 in the faculty.
99 " 10 " 20 " "
17 " 20 or over " "

If the statistics were forthcoming—and possibly they may exist—we might also get an idea of the standing of these institutions and their approach to the true university idea, by the average age of the scholars. Possibly also the ratio of number of scholars to teachers might be of some help. All these methods give an approximation to the present standing of the institutions. But there is another method of attacking the problem, which is very exact, but it only gives us the *possibilities* of which the institution is capable. I refer to the wealth of the institution. In estimating the wealth, I have not included the value of grounds and buildings, for this is of little importance, either to the present or future standing of the institution. As good work can be done in a hovel as in a palace. I have taken the productive funds of the institution as the basis of estimate. I find:

234 have below $500,000
8 " between $500,000 and $1,000,000
8 " over $1,000,000

There is no fact more firmly established, all over the world, than that the higher education can never be made to pay for itself. Usually the cost to a college, of educating a young man, very much exceeds what he pays for it, and is often three or four times as much. The higher the education, the greater this proportion will be; and a university of the highest class should anticipate only a small accession to its income from the fees of students. Hence the test I have applied must give a true representation of the possibilities in every case. According to the figures, only sixteen colleges and universities have $500,000 or over of invested funds, and only one-half of these have $1,000,000 and over. Now, even the latter sum is a very small endowment for a college; and to call any institution a university which has less than $1,000,000, is to render it absurd in the face of the world. And yet more than 100 of our institutions, many of them very respectable colleges, have abused the word 'university' in this manner. It is to be hoped that the endowment of the more respectable of these institutions may be increased, as many of them deserve it; and their unfortunate appellation has probably been repented of long since.

But what shall we think of a community that gives the charter of a university to an institution with a total of $20,000 endowment, two so-called professors, and eighteen students! or another with three professors, twelve students, and a total of $27,000 endowment, mostly

invested in buildings! And yet there are very many similar institutions; there being sixteen with three professors or less, and very many indeed with only four or five.

Such facts as these could only exist in a democratic country, where pride is taken in reducing everything to a level. And I may also say that it can only exist in the early days of such a democracy; for an intelligent public will soon perceive that calling a thing by a wrong name does not change its character, and that truth, above all things, should be taught to the youth of the nation.

It may be urged that all these institutions are doing good work in education; and that many young men are thus taught who could not afford to go to a true college or university. But I do not object to the education—though I have no doubt an investigation would disclose equal absurdities here—for it is aside from my object. But I do object to lowering the ideals of the youth of the country. Let them know that they are attending a school, and not a university; and let them know that above them comes the college, and above that the university. Let them be taught that they are only half-educated, and that there are persons in the world by whose side they are but atoms. In other words, let them be taught the truth.

It may be that some small institutions are of high grade, especially those which are new; but who can doubt that more than two-thirds of our institutions calling themselves colleges and universities are unworthy of the name? Each one of these institutions has so-called professors, but it is evident that they can be only of the grade of teachers. Why should they not be so called? The position of teacher is an honored one, but is not made more honorable by the assumption of a false title. Furthermore, the multiplication of the title, and the ease with which it can be obtained, render it scarcely worth striving for. When the man of energy, ability and perhaps genius is rewarded by the same title and emoluments as the commonplace man with the modicum of knowledge, who takes to teaching, not because of any aptitude for his work, but possibly because he has not the energy to compete with his fellow-men in business, then I say one of the inducements for first-class men to become professors is gone.

When work and ability are required for the position, and when the professor is expected to keep up with the progress of his subject, and to do all in his power to advance it, and when he is selected for these reasons, then the position will be worth working for, and the successful competitor will be honored accordingly. The chivalric spirit which prompted Faraday to devote his life to the study of nature may actuate a few noble men to give their life to scientific work; but, if we wish to cultivate this highest class of men in science, we must open a career for them worthy of their efforts.

Jenny Lind, with her beautiful voice, would have cultivated it to some extent in her native village; yet who would expect her to travel over the world, and give concerts for nothing? and how would she have been able to do so if she had wished? And so the scientific man, whatever his natural talents, must have instruments and a library, and a suitable and respectable salary to live upon, before he is able to exert himself to his full capacity. This is true of advance in all the higher departments of human learning, and yet something more is necessary. It is not those in this country who receive the largest salary, and have positions in the richest colleges, who have advanced their subject the most: men receiving the highest salaries, and occupying the professor's chair, are to-day doing absolutely nothing in pure science, but are striving by the commercial applications of their science to increase their already large salary. Such pursuits, as I have said before, are honorable in their proper place; but the duty of a professor is to advance his science, and to set an example of pure and true devotion to it which shall demonstrate to his students and the world that there is something high and noble worth living for. Money-changers are often respectable men, and yet they were once severely rebuked for carrying on their trade in the court of the temple.

Wealth does not constitute a university, buildings do not: it is the men who constitute its faculty, and the students who learn from them. It is the last and highest step which the mere student takes. He goes forth into the world, and the height to which he rises has been influenced by the ideals which he has consciously or unconsciously imbibed in his university. If the professors under whom he has studied have been high in their profession, and have themselves had high ideals; if they have considered the advance of their particular subject their highest work in life, and are themselves honored for their intellect throughout the world—the student is drawn toward that which is highest, and ever after in life has high ideals. But if the student is taught by what are sometimes called good teachers, and teachers only, who know little more than the student, and who are often surpassed and even despised by him, no one can doubt the lowered tone of his mind. He finds that by his feeble efforts he can surpass one to whom a university has given its highest honor and he begins to think that he himself is a born genius, and the incentive to work is gone. He is great by the side of the molehill, and does not know any mountain to compare himself with.

A university should not only have great men in its faculty, but have numerous minor professors and assistants of all kinds, and should encourage the highest work, if for no other reason than to encourage the student to his highest efforts.

But, assuming that the professor has high ideals, wealth such as

only a large and high university can command, is necessary to allow him the fullest development.

And this is specially so in our science of physics. In the early days of physics and chemistry, many of the fundamental experiments could be performed with the simplest apparatus. And so we often find the names of Wollaston and Faraday mentioned as needing scarcely anything for their researches. Much can even now be done with the simplest apparatus; and nobody, except the utterly incompetent, need stop for want of it. But the fact remains that one can only be free to investigate in all departments of chemistry and physics, when he not only has a complete laboratory at his command, but a friend to draw on for the expenses of each experiment. That simplest of the departments of physics, namely, astronomy, has now reached such perfection that nobody can expect to do much more in it without a perfectly equipped observatory; and even this would be useless without an income sufficient to employ a corps of assistants to make the observations and computations. But even in this simplest of physical subjects, there is great misunderstanding. Our country has very many excellent observatories: and yet little work is done in comparison, because no provision has been made for maintaining the work of the observatory; and the wealth which, if concentrated, might have made one effective observatory which would prove a benefit to astronomical science, when scattered among a half-dozen, merely furnishes telescopes for the people in the surrounding region to view the moon with. And here I strike the keynote of at least one need of our country, if she would stand well in science; and the following item which I clip from a newspaper will illustrate the matter:

"The eccentric old Canadian, Arunah Huntington, who left $200,000 to be divided among the public schools of Vermont, has done something which will be of little practical value to the schools. Each district will be entitled to the insignificant sum of $10, which will not advance much the cause of education."

Nobody will dispute the folly of such a bequest, or the folly of filling the country with telescopes to look at the moon, and calling them observatories. How much better to concentrate the wealth into a few parcels, and make first-class observatories and institutions with it!

Is it possible that any of our four hundred colleges and universities have love enough of learning to unite with each other and form larger institutions? Is it possible that any have such a love of truth that they are willing to be called by their right name? I fear not; for the spirit of expectation, which is analogous to the spirit of gambling, is strong in the American breast, and each institution which now, except in name, slumbers in obscurity, expects in time to bloom out into full prosperity. Although many of them are under religious influence,

where truth is inculcated, and where men are taught to take a low seat at the table in order that they may be honored by being called up higher, and not dishonored by being thrust down lower, yet these institutions have thrust themselves into the highest seats, and cannot probably be dislodged.

But would it not be possible to so change public opinion that no college could be founded with a less endowment than say $1,000,000, or no university with less than three or four times that amount? From the report of the Commissioner of Education I learn that such a change is taking place; that the tendency towards large institutions is increasing, and that it is principally in the West and Southwest that the multiplication of small institutions with big names is to be feared most, and that the East is almost ready for the great coming university.

The total wealth of the four hundred colleges and universities in 1880 was about $40,000,000 in buildings and $43,000,000 in productive funds. This would be sufficient for one great university of $10,000,000, four of $5,000,000, and twenty-six colleges of $2,000,000 each. But such an idea can of course never be carried out. Government appropriations are out of the question, because no political trickery must be allowed around the ideal institution.

In the year 1880 the private bequests to all schools and colleges amounted to about $5,500,000; and, although there was one bequest of $1,250,000, yet the amount does not appear to be phenomenal. It would thus seem that the total amount was about five million dollars in one year, of which more than half is given to so-called colleges and universities. It would be very difficult to regulate these bequests so that they might be concentrated sufficiently to produce an immediate result. But the figures show that generosity is a prominent feature of the American people, and that the needs of the country only have to be appreciated to have the funds forthcoming. We must make the need of research and of pure science felt in the country. We must live such lives of pure devotion to our science, that all shall see that we ask for money, not that we may live in indolent ease at the expense of charity, but that we may work for that which has advanced and will advance the world more than any other subject, both intellectually and physically. We must live such lives as to neutralize the influence of those who in high places have degraded their profession, or have given themselves over to ease, and do nothing for the science which they represent. Let us do what we can with the present means at our disposal. There is not one of us who is situated in the position best adapted to bring out all his powers, and to allow him to do most for his science. All have their difficulties, and I do not think that circumstances will ever radically change a man. If a man has the instinct of research in him, it will always show itself in some form.

But circumstances may direct it into new paths, or may foster it so that what would otherwise have died as a bud now blossoms and ripens into the perfect fruit.

Americans have shown no lack of invention in small things; and the same spirit, when united to knowledge and love of science, becomes the spirit of research. The telegraph-operator, with his limited knowledge of electricity and its laws, naturally turns his attention to the improvement of the only electrical instrument he knows anything about; and his researches would be confined to the limited sphere of his knowledge, and to the simple laws with which he is acquainted. But as his knowledge increases, and the field broadens before him, as he studies the mathematical theory of the subject, and the electromagnetic theory of light loses the dim haze due to distance, and becomes his constant companion, the telegraph-instrument becomes to him a toy, and his effort to discover something new becomes research in pure science.

It is useless to attempt to advance science until one has mastered the science: he must step to the front before his blows can tell in the strife. Furthermore, I do not believe anybody can be thorough in any department of science, without wishing to advance it. In the study of what is known, in the reading of the scientific journals, and the discussions therein contained of the current scientific questions, one would obtain an impulse to work, even though it did not before exist. And the same spirit which prompted him to seek what was already known, would make him wish to know the unknown. And I may say that I never met a case of thorough knowledge in my own science, except in the case of well-known investigators. I have met men who talked well, and I have sometimes asked myself why they did not do something; but further knowledge of their character has shown me the superficiality of their knowledge. I am no longer a believer in men who could do something if they would, or would do something if they had a chance. They are impostors. If the true spirit is there, it will show itself in spite of circumstances.

As I remarked before, the investigator in pure science is usually a professor. He must teach as well as investigate. It is a question which has been discussed in late years, as to whether these two functions would better be combined in the same individual, or separated. It seems to be the opinion of most that a certain amount of teaching is conducive, rather than otherwise, to the spirit of research. I myself think that this is true, and I should myself not like to give up my daily lecture. But one must not be overburdened. I suppose that the true solution, in many cases, would be found in the multiplication of assistants, not only for the work of teaching but of research. Some men are gifted with more ideas than they can work out with their own

hands, and the world is losing much by not supplying them with extra hands. Life is short: old age comes quickly, and the amount one pair of hands can do is very limited. What sort of shop would that be, or what sort of factory, where one man had to do all the work with his own hands? It is a fact in nature, which no democracy can change, that men are *not* equal—that some have brains and some hands. And no idle talk about equality can ever subvert the order of the universe.

I know of no institution in this country where assistants are supplied to aid directly in research. Yet why should it not be so? And even the absence of assistant professors and assistants of all kinds, to aid in teaching, is very noticeable, and must be remedied before we can expect much.

There are many physical problems, especially those requiring exact measurements, which cannot be carried out by one man, and can only be successfully attacked by the most elaborate apparatus, and with a full corps of assistants. Such are Regnault's experiments on the fundamental laws of gases and vapors, made thirty or forty years ago by aid from the French Government, and which are the standards to this day. Although these experiments were made with a view to the practical calculation of the steam engine, yet they were carried out in such a broad spirit that they have been of the greatest theoretical use. Again, what would astronomy have done without the endowments of observatories? By their means, that science has become the most perfect of all branches of physics, as it should be from its simplicity. There is no doubt, in my mind, that similar institutions for other branches of physics, or, better, to include the whole of physics, would be equally successful. A large and perfectly equipped physical laboratory with its large revenues, its corps of professors and assistants, and its machine shop for the construction of new apparatus, would be able to advance our science quite as much as endowed observatories have astronomy. But such a laboratory should not be founded rashly. The value will depend entirely on the physicist at its head, who has to devise the plan, and to start it into practical working. Such a man will always be rare, and cannot always be obtained. After one had been successfully started, others could follow; for imitation requires little brains.

One could not be certain of getting the proper man every time, but the means of appointment should be most carefully studied so as to secure a good average. There can be no doubt that the appointment should rest with a scientific body capable of judging the highest work of each candidate.

Should any popular element enter, the person chosen would be either of the literary-scientific order, or the dabbler on the outskirts who presents his small discoveries in the most theatrical manner. What

is required is a man of depth, who has such an insight into physical science that he can tell when blows will best tell for its advancement.

Such a grand laboratory as I describe does not exist in the world, at present, for the study of physics. But no trouble has ever been found in obtaining means to endow astronomical science. Everybody can appreciate, to some extent, the value of an observatory; as astronomy is the simplest of scientific subjects, and has very quickly reached a position where elaborate instruments and costly computations are necessary to further advance. The whole domain of physics is so wide that workers have hitherto found enough to do. But it cannot always be so, and the time has even now arrived when such a grand laboratory should be founded. Shall our country take the lead in this matter, or shall we wait for foreign countries to go before? They will be built in the future, but when and how is the question.

Several institutions are now putting up laboratories for physics. They are mostly for teaching, and we can expect only a comparatively small amount of work from most of them. But they show progress; and, if the progress be as quick in this direction as in others, we should be able to see a great change before the end of our lives.

As stated before, men are influenced by the sympathy of those with whom they come in contact. It is impossible to immediately change public opinion in our favor; and, indeed, we must always seek to lead it, and not be guided by it. For pure science is the pioneer that must not hover about cities and civilized countries, but must strike into unknown forests, and climb the hitherto inaccessible mountains which lead to and command a view of the promised land—the land that science promises us in the future; which shall not only flow with milk and honey, but shall give us a better and more glorious idea of this wonderful universe. We must create a public opinion in our favor, but it need not be at first the general public. We must be contented to stand aside, and see the honors of the world for a time given to our inferiors; and must be better contented with the approval of our own consciences, and of the very few who are capable of judging our work, than of the whole world beside. Let us look to the other physicists, not in our own town, not in our own country, but in the whole world, for the words of praise which are to encourage us, or the words of blame which are to stimulate us to renewed effort. For what to us is the praise of the ignorant? Let us join together in the bonds of our scientific societies, and encourage each other, as we are now doing, in the pursuit of our favorite study; knowing that the world will some time recognize our services, and knowing, also, that we constitute the most important element in human progress.

But danger is also near, even in our societies. When the average tone of the society is low, when the highest honors are given to the

mediocre, when third-class men are held up as examples, and when trifling inventions are magnified into scientific discoveries, then the influence of such societies is prejudicial. A young scientist attending the meetings of such a society soon gets perverted ideas. To his mind, a molehill is a mountain, and the mountain a molehill. The small inventor or the local celebrity rises to a greater height, in his mind, than the great leader of science in some foreign land. He gauges himself by the molehill, and is satisfied with his stature; not knowing that he is but an atom in comparison with the mountain, until, perhaps, in old age, when it is too late. But, if the size of the mountain had been seen at first, the young scientist would at least have been stimulated in his endeavor to grow.

We cannot all be men of genius; but we can, at least, point them out to those around us. We may not be able to benefit science much ourselves; but we can have high ideals on the subject, and instil them into those with whom we come in contact. For the good of ourselves, for the good of our country, for the good to the world, it is incumbent on us to form a true estimate of the worth and standing of persons and things, and to set before our own minds all that is great and good and noble, all that is most important for scientific advance, above the mean and low and unimportant.

It is very often said that a man has a right to his opinion. This might be true for a man on a desert island, whose error would influence only himself. But when he opens his lips to instruct others, or even when he signifies his opinions by his daily life, then he is directly responsible for all his errors of judgment or fact. He has no right to think a molehill as big as a mountain, nor to teach it, any more than he has to think the world flat, and teach that it is so. The facts and laws of our science have *not* equal importance, neither have the men who cultivate the science achieved equal results. One thing is greater than another, and we have no right to neglect the order. Thus shall our minds be guided aright, and our efforts be toward that which is the highest.

Then shall we see that no physicist of the first class has ever existed in this country, that we must look to other countries for our leaders in that subject, and that the few excellent workers in our country must receive many accessions from without before they can constitute an American science, or do their share in the world's work.

But let me return to the subject of scientific societies. Here American science has its hardest problem to contend with. There are very many local societies dignified by high-sounding names, each having its local celebrity, to whom the privilege of describing some crab with an extra claw, which he found in his morning ramble, is inestimable. And there are some academies of science, situated at our seats of learn-

ing, which are doing good work in their locality. But distances are so great that it is difficult to collect men together at any one point. The American Association, which we are now attending, is not a scientific academy, and does not profess to be more than a gathering of all who are interested in science, to read papers and enjoy social intercourse. The National Academy of Sciences contains eminent men from the whole country, but then it is only for the purpose of advising the government freely on scientific matters. It has no building, it has no library; and it publishes nothing except the information which it freely gives to the government, which does nothing for it in return. It has not had much effect directly on American science; but the liberality of the government in the way of scientific expeditions, publications, etc., is at least partly due to its influence, and in this way it has done much good. But it in no way takes the place of the great Royal Society, or the great academies of science at Paris, Berlin, Vienna, St. Petersburg, Munich, and, indeed, all the European capitals and large cities. These, by their publications, give to the young student, as well as the more advanced physicist, models of all that is considered excellent; and to become a member is one of the highest honors to which he can aspire, while to write a memoir which the academy considers worthy to be published in its transactions excites each one to his highest effort.

The American Academy of Sciences in Boston is perhaps our nearest representation of this class of academies, but its limitation of membership to the State deprives it of its national character.

But there is another matter which influences the growth of our science.

As it is necessary for us still to look abroad for our highest inspiration in pure science, and as science is not an affair of one town or one country, but of the whole world, it becomes us all to read the current journals of science and the great transactions of foreign societies, as well as those of our own countries. These great transactions and journals should be in the library of every institution of learning in the country, where science is taught. How can teachers and professors be expected to know what has been discovered in the past, or is being discovered now, if these are not provided? Has any institution a right to mentally starve the teachers whom it employs, or the students who come to it? There can be but one answer to this; and an institution calling itself a university, and not having the current scientific journals upon its table or the transactions of societies upon its library shelves, is certainly not doing its best to cultivate all that is best in this world.

We call this a free country, and yet it is the only one where there is a direct tax upon the pursuit of science. The low state of pure

science in our country may possibly be attributed to the youth of the country; but a direct tax, to prevent the growth of our country in that subject, cannot be looked upon as other than a deep disgrace. I refer to the duty upon foreign books and periodicals. In our science, no books above elementary ones have ever been published, or are likely to be published, in this country; and yet every teacher in physics must have them, not only in the college library, but on his own shelves, and must pay the government of this country to allow him to use a portion of his small salary to buy that which is to do good to the whole country. All freedom of intercourse which is necessary to foster our growing science is thus broken off; and that which might, in time, relieve our country of its mediocrity, is nipped in the bud by our government, which is most liberal when appealed to directly on scientific subjects.

One would think that books in foreign languages might be admitted free; but to please the half-dozen or so workmen who reprint German books, not scientific, our free intercourse with that country is cut off. Our scientific associations and societies must make themselves heard in this matter, and show those in authority how the matter stands.

In conclusion, let me say once more, that I do not believe that our country is to remain long in its present position. The science of physics, in whose applications our country glories, is to arise among us, and make us respected by the nations of the world. Such a prophecy may seem rash with regard to a nation which does not yet do enough physical work to support a physical journal. But we do know the speed with which we advance in this country: we see cities springing up in a night, and other wonders performed at an unprecedented rate. And now we see physical laboratories being built, we see a great demand for thoroughly trained physicists, who have not shirked their mathematics, both as professors and in so-called practical life; and perhaps we have the feeling, common to all true Americans, that our country is going forward to a glorious future, when we shall lead the world in the strife for intellectual prizes as we now do in the strife for wealth.

But if this is to be so, we must not aim low. The problems of the universe cannot be solved without labor: they cannot be attacked without the proper intellectual as well as physical tools; and no physicist need expect to go far without his mathematics. No one expects a horse to win in a great and long race who has not been properly trained; and it would be folly to attempt to win with one, however pure his blood and high his pedigree, without it. The problems we solve are more difficult than any race: the highest intellect cannot hope to succeed without proper preparation. The great prizes are reserved for the

greatest efforts of the greatest intellects, that have kept their mental eye bright and flesh hard by constant exercise. Apparatus can be bought with money, talents may come to us at birth; but our mental tools, our mathematics, our experimental ability, our knowledge of what others have done before us, all have to be obtained by work. The time is almost past, even in our own country, when third-rate men can find a place as teachers, because they are unfit for everything else. We wish to see brains and learning, combined with energy and immense working-power, in the professor's chair; but, above all, we wish to see that high and chivalrous spirit which causes one to pursue his idea in spite of all difficulties, to work at the problems of nature with the approval of his own conscience, and not of men before him. Let him fit himself for the struggle with all the weapons which mathematics and the experience of those gone before him can furnish, and let him enter the arena with the fixed and stern purpose to conquer. Let him not be contented to stand back with the crowd of mediocrity, but let him press forward for a front place in the strife.

The whole universe is before us to study. The greatest labor of the greatest minds has given us only a few pearls; and yet the limitless ocean, with its hidden depths filled with diamonds and precious stones, is before us. The problem of the universe is yet unsolved, and the mystery involved in one single atom yet eludes us. The field of research only opens wider and wider as we advance, and our minds are lost in wonder and astonishment at the grandeur and beauty unfolded before us. Shall we help in this grand work, or not? Shall our country do its share, or shall it still live in the almshouse of the world?

THE MALARIA-GERM AND ALLIED FORMS OF SPOROZOA.

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THE group of animal parasites to which the malaria-causing organism belongs is relatively unimportant when compared with the bacteria, a group of plant parasites, including the causes of most zymotic diseases in man—typhoid, cholera, diphtheria, scarlet fever, tuberculosis and the like, as well as beneficial forms which aid man in various ways. Nevertheless, it is a group of considerable economic importance, about which little is known outside of scientific circles. The name Sporozoa suggests, to the average reader, no disquieting apprehension of physical pain or of financial loss, yet this class of primitive, unicellular animals includes, besides the malaria-causing blood parasites, forms which, like the silkworm parasite *(Glugea bombycis)*, have cost communities untold millions of dollars. In connection with the losses due to one of these silkworm epidemics, Huxley writes in 1870:

"In the years following 1853 this malady broke out with such extreme violence that, in 1853, the silk crop was reduced to a third of the amount which it had reached in 1853; and up till within the last year or two it has never attained half the yield of 1853. This means not only that the great number of people engaged in silk growing are some thirty millions sterling poorer than they might have been; it means not only that high prices have had to be paid for imported silkworm eggs, and that, after investing his money in them, in paying for mulberry leaves and for attendance, the cultivator has constantly seen his silkworms perish and himself plunged in ruin; but it means that the looms of Lyons have lacked employment, and that, for years, enforced idleness and misery have been the portion of a vast population which, in former days, was industrious and well to do."

Analogous epidemics, which may be traced to Sporozoa, are liable to break out at any time among other animals having commercial value. Thus 'Texas fever,' a cattle disease due to a sporozoan blood parasite *(Piroplasma bigeminum)*, occasions great loss to cattle breeders. Muscle parasites, belonging to the same class, cause trichinosis-like diseases in hogs, cows, cats, dogs and other domestic animals; while in fish they occasion great loss to fish-culturists through epidemics. Other parasites in the same class are the causes of disease in horses, sheep, goats, etc.

The Sporozoa are comparatively harmless to man personally, but, unlike some bacteria, they are never beneficial in any sense. Invariably parasites, the diseases which they induce are confined mainly to the lower animals, but so widely are they distributed that no type of animals is free from them altogether. One significant feature about the

Sporozoa is that, notwithstanding the many kinds and the wide distribution in all sorts of hosts, the life history of the parasites invariably conforms to the same type, a fact which has recently been used to good advantage in working out the development of the malaria organism.

Like all the unicellular animals, or Protozoa, the Sporozoa are minute bits of protoplasm provided with a membrane and a specialized spherical portion of the inner protoplasm called the nucleus. Unlike the other Protozoa, they are entirely devoid of motile organs and are, in consequence, quiescent. In classifying them, advantage has been taken of the different modes in which they form spores, or germs, by which they are reproduced. In some, known as the *Telosporidia*, all the protoplasm of the parasite is used to form the spores, and the parent cell dies or disappears with each sporulation, which thus represents the end of the individual parasite. The individuals of the second group, known as the *Neosporidia*, form spores, without using all the protoplasm, and continue to live after each sporulation. This group comprises the less-known forms of Sporozoa, and is of considerable economic importance as the cause of epidemics among silkworms, brook trout and other fish, etc.

The Telosporidia are further divided according to the mode of life. Some of them, known as the *Gregarinida*, live in cavities of the body of many forms of invertebrates, but rarely in vertebrates; others, the *Coccidia*, live in epithelial cells lining the cavities of both invertebrate and vertebrate hosts. It may be remarked, parenthetically, that the cause of cancerous growths in man is claimed by many to be organisms belonging to this group of Sporozoa. The question remains in considerable doubt, however, and, despite the great mass of literature, no positive results have appeared. The last group finally of the Telosporidia is the *Hæmosporidia*, comprising parasites which, like the malaria-organism—*Plasmodium malariæ*—live in blood corpuscles of vertebrates.

All these different types of Telosporidia begin life as minute germs called *sporozoites*, which make their way into the new host through the intestine, being taken in with the food. The life history, after this ingestion, follows slightly modified paths in the different types, and, for purposes of comparison, I will describe these processes in the gregarine, the coccidium and in the hæmospore *Plasmodium malariæ*, thus representing each of the subdivisions of the Telosporidia.

The sea-squirt, or Tunicate, *Ciona intestinalis*, is the host of a gregarine *Monocystis ascidiæ*, which is so widely distributed that it is almost impossible to find a *Ciona* without them. The complete life history of the parasite has been fully worked out by Prof. M. Siedlecki,

of Cracow University, Russia, whose results form the basis of the following account*:

The description of the life cycle may begin with the sporozoite, or youngest form, of the gregarine parasite. This is a small, elongate germ which makes its way through the fluids of the digestive tract of *Ciona* to the epithelial cells which line that canal. (Fig. 1, A.) The sporozoite penetrates one of these cells and begins to grow at the expense of the cell contents, until, finally, too large for the cell host, it breaks the cell wall and falls into the lumen of the digestive tract, where it soon attains its full size. (Fig. 1, B. C. D.) It is now a comparatively large, sac-like cell, swollen at one end, and with a distinct nucleus. (Fig. 1, C.) After a longer or shorter period, not definitely determined, two adult forms come together and pour out a sticky, fluid substance, which soon hardens to form a common, firm covering, or cyst. (Fig. 1, E.) Each nucleus then begins to divide, and, after a multitude of daughter-nuclei have arisen, the protoplasm of the cell breaks up into as many parts as there are nuclei (Fig. 1, F. G. H.). These small protoplasmic parts *(gametes)* then wander out of the parent membranes and ultimately fuse, two by two, while still remaining in the original cyst wall (Fig. 1, I. J.). After the fusion, the nucleus and protoplasm in each double mass divides into eight parts, and a firm, enveloping membrane is secreted about them. This spore-membrane ultimately becomes impregnated with calcareous material, which thus forms a firm and resisting capsule for the eight germs within. Each germ is a sporozoite similar to the one which began the life cycle.

During the process of sporozoite-formation, the parasite is passed out with the fæces to the exterior. Here the original cyst ultimately bursts and liberates the multitude of spores with their contained sporozoites. The latter are well protected, however, by their calcareous shells, and do not suffer from the sea water or from drying. The spores may be finally taken into the digestive tract with food, and with this the opportunity for a renewed cycle is presented. The acids of the digestive fluids dissolve the calcareous coverings, and the eight sporozoites in each spore are liberated. The sporozoites again penetrate the epithelial cells, grow to maturity and repeat the process indefinitely.

In *Coccidium*, a parasite of some of the insects, the life history as worked out by Dr. F. Schaudinn differs in one or two important points from that of the gregarine.

Sporozoites are formed as in the previous case, and these work their way in a similar manner into the cells lining the digestive tract (Fig 2, *a*). Unlike the gregarine, the main period of their life is passed in these cells, and they drop into the lumen of the intestine only when they

* Siedlicki. Ueber die geschlechliche Vermehrung der Monocystis ascidiæ R. Lank. Bull. d. l'Acad. d. Sci. d. Cracovie, December, 1899.

are ready to form spores. The nucleus divides repeatedly, and a great number of buds are formed around the daughter nuclei (Fig. 2, *b*, *c*). These buds elongate from the periphery of the parent organism and radiate from it, like the spines of a sea urchin. When fully developed, the spores, or, as they are technically known, the *merozoites*, drop off the parent cell and work their way through the fluids of the digestive tract until they come to the cells lining it, and then, like the sporozoites, they penetrate the cells, grow at their expense, and again reproduce spores as before (Fig 2, *a* to *c*). This process thus tends to spread the disease among the cells of the digestive tract in the one host, and it will be observed that the reproductive process is not accompanied by the union of two gametes, as in the case of *Monocystis*. *Coccidium* is thus distinguished from the latter in having a method of asexual multiplication leading to auto-infection. This process, however, cannot continue indefinitely, and, after five or six days, a method of sexual multiplication supervenes. The preliminary stages of this process do not differ from the formation of the merozoites, and similar buds are formed which break off and penetrate the epithelial cells as before. The further history, however, differs markedly from that of the merozoite. Some of the resulting parasites give rise to immense numbers of minute, active, thread-like buds, the *microgametes*, which radiate from the parent cell like the merozoites *(h—j)*. Others do not form buds at all, but merely enlarge until they are as large, or larger than, the ordinary full-grown parasites *(d—f)*. One of the small forms then fuses with a large form, in conjunction; and the result, or *copula*, secretes a firm cyst about itself, and then divides into spores (2, *g*). Each spore then secretes about itself a second coating which becomes impregnated with calcareous matter, and, within this cyst, the cell divides into a small number of sporozoites *(k)*. In this condition the primary cysts are emptied to the outside, where they are ultimately taken up by some new host in whose digestive tract the cysts are dissolved and the sporozoites liberated to renew the cycle (Fig. 2, *l*).

It thus appears that, in *Coccidium*, the life cycle is more complicated than in the gregarine, in having a period of asexual reproduction by which auto-infection is accomplished, alternating with a period of sexual multiplication during which the parasite is carried from one host to another. *Coccidium* differs further from *Monocystis* in that the conjugating gametes are sexually differentiated, the small, active one, or microgamete, functions as the male cell, and the larger, quiescent one, or macrogamete, as the female or egg cell, while in the gregarine, on the other hand, the conjugating gametes are of equal size.

We may now consider the somewhat more complicated life cycle of the malaria organism. The process of spore-formation of this para-

site, in the blood cells of the human host, was correctly made out in 1888 by two Italian naturalists, Marchiafava and Celli, who showed that the young parasite, in a red blood corpuscle, is a minute granule in which no structure could be made out. The granule grows, however, at the expense of the hæmaglobin of the corpuscle, and ultimately forms spores (Fig. 3, *a*—*f*). During the life of the parent organism, the products of growth are stored up in the parasite in the form of fine gran-

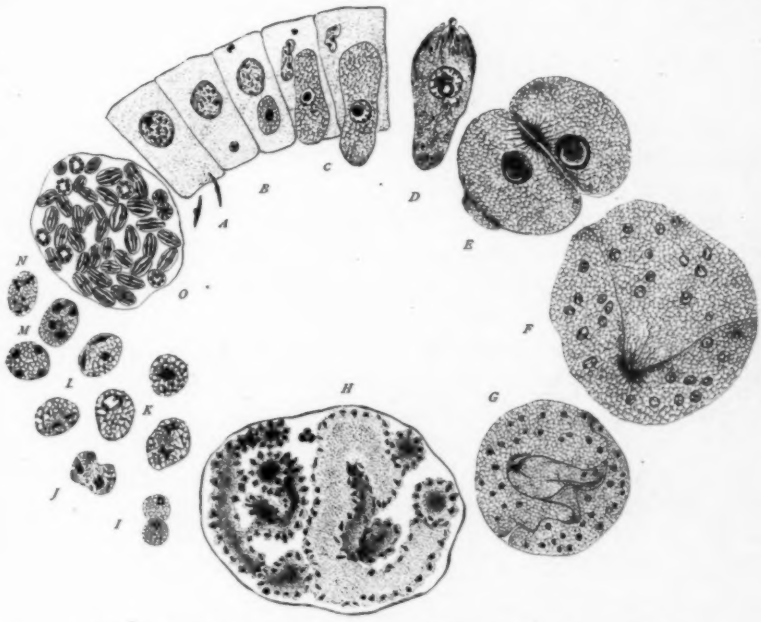

FIG. 1. LIFE CYCLE OF A GREGARINE. [MAINLY AFTER SIEDLECKI.]

Minute germs, sporozoites (A), enter epithelial cells lining the digestive tract of a tunicate. Here they grow to a large size (B, C), ultimately breaking through a cell-membrane and falling into the lumen of the digestive tract (D). After some time in this adult condition, two individuals come together (E). The nuclei divide repeatedly (F, G), and minute gametes are ultimately formed (H, I). The gametes then fuse, two by two (I, J), forming the spores. The two nuclei also fuse (K), and the joint nucleus then divides three times in succession (L, M, N), forming right daughter-nuclei, which become the nuclei of eight germs or sporozoites (O). The sporozoites are inclosed in small calcareous capsules which, in a new host, are dissolved by the acids of the digestive fluids, thus setting free the sporozoites (A).

ules. These, known as *melanin* granules, are left in the center of the parent organism when the spores are formed, but at this period the blood corpuscle, in which the sporulation occurs, disintegrates, and so liberates the spores and the melanin in the blood plasm. Like the merozoites of *Coccidia*, these spores make their way to new corpuscles, which they

enter, and in which they repeat the cycle, thus bringing about auto-infection.

Another Italian naturalist, Golgi, in 1889, showed that the spore-formation of the parasites and the well-known pyrexial attacks on the part of the patient occur at the same time, and the phenomena were interpreted as cause and effect. The direct cause of the attack was then found to be the liberation into the blood plasm of the melanin

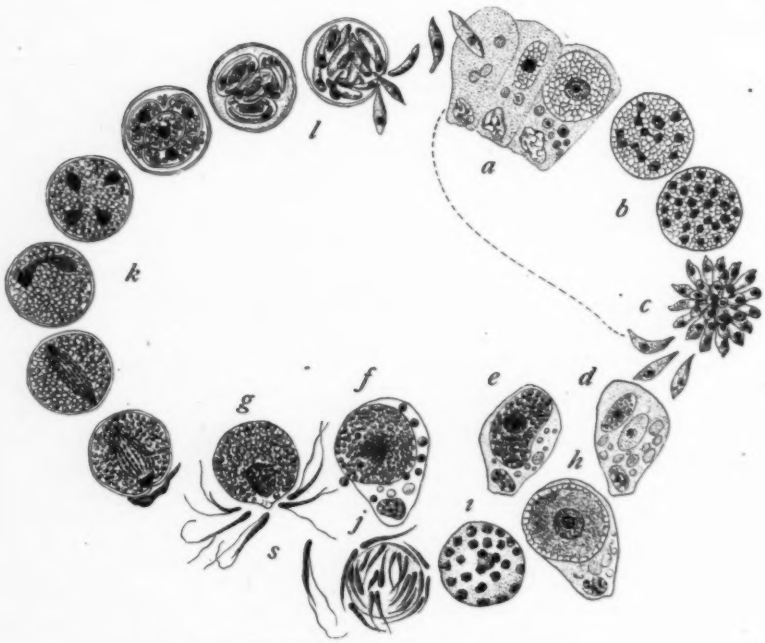

FIG. 2. LIFE CYCLE OF COCCIDIUM. [SCHAUDINN.]

The sporozoites penetrate epithelial cells (*a*) and grow to adult size. When ready to sporulate, they are free in the lumen of the organ. The nucleus divides repeatedly (*b*) and each of the ultimate sub-divisions becomes the nucleus of a merozoite (*c*). These re-enter epithelial cells (*a*) and repeat the cycle. After five or six days the merozoites have a different fate. Some (*d*—*g*) enlarge and form egg-cells; others (*h*—*j*) form minute flagellated male cells, or microgametes. One of these fuses with one egg cell, (*g*—*k*), and the copula then forms spores (*k*), each of which form, in turn, two sporozoites (*l*). In this condition the organism is taken into a new host and the process is then repeated.

granules, which, acting like a poison, throw the entire system into disorder. In different types of malaria, the attacks sometimes occur every 72 hours, sometimes every 48 hours, and in some cases at irregular intervals. These different effects are produced by slightly different forms of the malaria organism. One form, known as *Plasmodium malariæ*, sporulates every 72 hours; another, *Plasmodium*

vivax, every 48 hours. Another form, giving rise to a more malignant type of malaria, is *Laverania malariæ*, which probably sporulates every 48 hours. In some types of the disease it is supposed that two or more

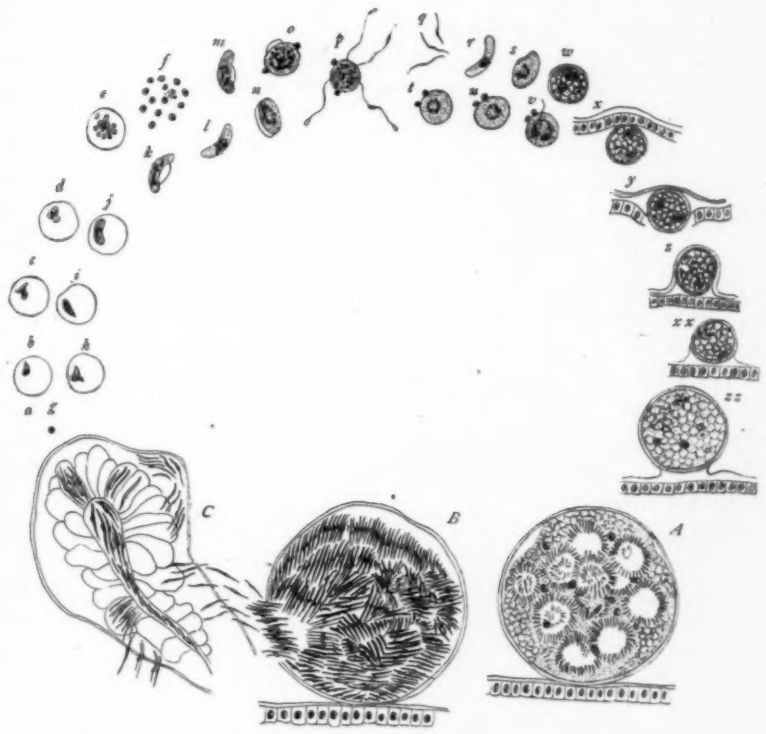

Fig. 3. LIFE CYCLE OF THE MALARIA-ORGANISM. [PARTLY AFTER ROSS AND FIELDING-OULD.]

The young sporozoites (*a*) penetrate red blood corpuscles and grow at the expense of the hæmaglobin (*b*—*d*). Spores (*e*—*f*) are finally formed and the growth products (melanin) are liberated. These spores, or merozoites, enter new blood cells and repeat the process (auto-infection). When taken into the stomach of the mosquito *Anopheles*, the parasites become much larger, some develop male gametes (*o*, *p*, *q*) on the *Polymitus* form (*p*); others, female gametes (*r*—*u*). These conjugate (*v*) in the stomach of *Anopheles*, and the copula (*w*) penetrates the epithelial lining of the stomach and ultimately lies suspended in the body cavity (*x*—*zz*). When mature, the parasite forms spores (A), which form, in turn, naked sporozoites (B). The sporozoites are liberated into the body cavity, and finally penetrate the salivary gland of the mosquito (C), from which they are emptied out with the fluid from the gland into the blood of a human host.

species may be present at the same time, and, sporulating at different intervals, may give rise to irregular attacks.

Until 1896, the life history of the parasite, as outlined above, was regarded as incomplete because of the perplexing form discovered in

the blood of malaria patients by Professor Danilewsky, in 1891. This form differed from the ordinary parasites in having many fine, flagelliform appendages, which, breaking away from the parent, would swim about freely in the surrounding fluid (Fig. 3, *p*). Danilewsky regarded this form as an independent blood parasite, and gave to it the name *Polymitus*. In a sense, *Polymitus* has been the key to the life history of the malaria organism, and its history has been the history of the further discoveries upon malaria. In France, Laveran regarded Danilewsky's discovery as indicating some stage in the cycle of *Plasmodium malariæ*, and not as an independent organism, while Labbé considered *Polymitus* a degenerate condition of the ordinary parasites and without further significance. The English specialist on tropical diseases, Dr. Manson, found that the malaria parasites, when exposed with the blood to the cooler air, very soon assume the *Polymitus* form, which he regarded as the extra-corporeal form assumed by the malaria-organism, for, he argued, the wide distribution of malaria, the spread from individual to individual, can be explained, since the disease is not contagious, only by the assumption of germs outside of the body. Furthermore, he suggested that these germs might be carried from person to person, by insects, such as the mosquito. In the same year, Laveran made an identical suggestion quite independently of Manson. It was not altogether novel, however, with either of these investigators; thus a certain mosquito in central Africa is known to the natives as the fever organism, while the same idea was represented in Theobald Smith's discovery (1893) of the tick as the agent in the transmission of the 'Texas fever' of cattle.

The first positive results on the significance of the *Polymitus* form were obtained by MacCallum, in Washington, in 1897-'98. A similar *Polymitus* form is developed by the malaria-organism of birds *(Halteridium)*, and, in the blood of diseased crows, MacCallum observed the filamentous motile bodies of the *Polymitus* form, break away from the central mass, and unite with an ordinary parasite. The result of the conjugation was a copula with an independent motion, by which it made its way through the surrounding fluids. The later history of the copula was not followed; similar observations were made, by the same observer, upon living malaria-organisms of man, and the *Polymitus* 'flagella' were seen to unite with larger forms of the parasite.

In the meantime, Major Ross, in India, was working out the mosquito hypothesis of Manson and Laveran, and succeeded in placing that theory upon a very substantial basis. He found black pigment granules, in the intestine and epithelial cells of the mosquito, which were identified as melanin granules of the blood parasite. It was also found, by Ross, that only certain kinds of mosquitoes were selected by the malaria parasites, *viz.:* various species of the genus *Anopheles*

by the human parasite, while species of the genus *Culex* were selected by the malaria parasites of birds. The full history, finally, has been worked out in complete detail during the last two years, by Ross again, and by Grassi, in Italy, and both observers reached quite independent, but identical, results. Briefly summarizing these results, the full life history of *Plasmodium malariæ* may be given as follows:

The early form of the parasite, which corresponds with the sporozoites of the gregarine and of *Coccidium*, penetrates a red blood corpuscle, grows to adult size, and then forms spores (Fig. 3, *a*—*b*). These correspond exactly with the merozoites of the *Coccidia*, and, like them, lead to auto-infection. At this point there is a gap in the evidence, for it is not known how long this asexual method of increase may continue; as shown above in the case of *Coccidium*, the spore-forming period continues for five or six days, when a period of conjugation supervenes. It may be stated here, parenthetically, that in all Protozoa, so far as known, a period of conjugation is necessary at some time during the life cycle, and without such conjugation, the organisms, which are reproduced asexually, finally decrease in size and show other signs of degeneration, ultimately resulting in death of the race (see results of Bütschli, Maupas, Hertwig, etc., upon degenerating Protozoa).

This is of considerable moment in the question of malaria, for, if the malaria-organism conforms to other Protozoa, there must come a time when this asexual sporulation will cease in any given set of individuals, and a period of conjugation must supervene to give renewed vigor to the parasites. So far as known at the present time, this conjugation takes place only in the digestive tract of the mosquito. That it does actually take place, is undeniable from the observations of MacCallum, Ross, Grassi and others, and the conjugants again as in *Coccidium*, are: a small, motile, microgamete, or male cell (one of the 'flagella' of the *Polymitus* form); and a larger macrogamete, or female, cell (Fig. 3, *p*—*v*). Their union, observed by Ross and Grassi, takes place in the stomach of *Anopheles*, and the copula then makes its way into, and through, the epithelial cells lining the stomach, and finally rests against the tissue which lines the body cavity. Here it grows to a relatively large size (Fig. 3, *w*—*zz*), and, when mature, its nucleus divides as in the gregarine or in *Coccidium*, to form a number of spores. Each of these develops a number of germs, or sporozoites, but, unlike the sporozoites of the previously described Sporozoa, these germs have no protective capsule about them, and, when the parent cyst ultimately bursts, they are liberated directly into the body cavity of the mosquito (Fig. 3, A, B). Here, in the fluids of the body cavity, they are carried to all parts of the organism, and finally reach the anterior region of the thorax, where the

salivary glands of the insect are located. They work their way through the cell wall of this gland, into the gland cells, from which they are drawn with the secretion and are finally poured into the lumen of the gland (Fig. 3, C). When the proboscis of the mosquito is inserted into a human host, and the salivary secretion is poured out, the sporozoites pass with it into the blood, and thus effect infection of a new host. Provided with their new potential of vitality resulting from conjugation, the young sporozoites grow and multiply in the blood corpuscles until they are numerous enough to cause the well-known symptoms of malaria. Coming from the same brood, so to speak, they have a similar rate of growth and multiplication, and so liberate their melanin granules throughout the blood system of their human host, at approximately the same time.

The question is frequently asked: Is the mosquito the only agent in the transmission of malaria? and when this is answered by the somewhat modified affirmative, 'Yes, so far as we know,' it is usually followed by the query: 'Why does malaria follow bad drainage, the digging of sewers, laying of gas pipes, etc.?' This question may be answered in two ways: First, it must be shown that these so-called malarial fevers, which accompany such conditions, are in reality true malaria; it is quite possible that hasty diagnosis in many cases gives a wrong impression of the prevalence of this disease. Second, it is conceivable that sporozoites may be carried in the blood, as typhoid is said to be frequently carried in the digestive tract, without causing symptoms of the disease until the natural resistance of the host is weakened by decreased vitality, which may be brought about by bad air, or by other means.

It is quite possible that some other means of transmission than the mosquito exists. The flea, for example, and other insects that prey on man must be examined with this end in view. There is no reason to believe that the sporozoites can be liberated in water, or suspended in the dust of the air, and live, for, of all Sporozoa, the blood-infesting forms are not protected against an external life. Thus we have seen that the sporozoites of the gregarine or of *Coccidium* are incased in a firm, calcareous shell, which protects them from drying and from other dangers that might be encountered. With the malaria-organism there is no such coating; the sporozoites are at all times naked bits of protoplasm, which soon dry up and die, when exposed to the air or placed in water. This fact also refutes the argument made by Bignami and others that the parasites are transferred directly from one individual to another by sticking to the proboscis. It is probable that the mosquito is the original, or primary, host of the malaria-organism, and that man and birds are secondary hosts, from which the parasites return to the primary one for the vital function of conjugation.

THE WILD BIRD AT ARM'S LENGTH: A NEW METHOD OF BIRD STUDY.*

By Professor FRANCIS H. HERRICK,
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IN the study of wild birds the problem of approach has always been difficult to master. The land birds of every continent are, as a rule, shy and difficult to study with that minuteness of detail which alone can satisfy the naturalist and careful observer of their habits.

Birds have enemies to fear and shun, and their discrimination does not exclude their most ardent or curious admirers from their bitterest foes. With them the battle is not always to the strong. Timidity, agility, protective colors and the instinct of concealment are as important in the struggle for life as the bill-hook and mailed foot. We speak of *wild* birds or of *wild animals* generally in contrast to the comparatively few which are tame, and if the wilderness does not always howl, it is often because its inhabitants have found it better policy to remain silent.

Wildness is due to fear which may be inherited or acquired by experience with this wicked world. Tameness on the other hand comes only through the casting out of fear, and may be effected by the formation of new habits, which are either spontaneous or forced. In order to tame a wild animal we must therefore teach it new lessons, and in doing this it is a common practice to literally chain it to a fixed spot, where its conditions of life are uniform and under control, and where no other teachers are allowed to interfere. The moment, however, the wild bird is placed in a cage its behavior is no longer perfectly spontaneous or free, at least not until all fear has been subdued. What is needed, therefore, is an invisible chain to hold the animals to some fixed and chosen spot, which may be approached in disguise.

Fortunately for the student of birds all these conditions are fulfilled for a very important period—that of life at the nest. The *nest* with its *young* is the given fixed point, and *parental instinct* is the invisible chain.

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* Messrs. G. P. Putnam's Sons will shortly publish a book by Professor Herrick, in which the original method described in this paper will be given in greater detail, and the interesting results obtained will be more fully set forth. The book will be entitled 'The Home-Life of Wild Birds: A New Method of Bird Study and Bird Photography,' and will contain upwards of 140 illustrations from nature.—Editor.

II.

The method of the study and photography of birds now to be described consists in first bringing the birds to you and then camping beside them. They can thus be watched and photographed at arm's length, or even as near as one would hold a book to read, and under the most perfect conditions of light and position, for hours or days at a time, while quite unconscious of being observed.

FIG. 1. FEMALE CHESTNUT-SIDED WARBLER, BROODING HER YOUNG ON A WARM DAY.

To be more explicit the method depends mainly upon two conditions: (1) The control of the nest or nesting site, and (2) the concealment of the observer.

If the nest like that of an Oriole, Robin, Flycatcher, Waxwing or Vireo is fastened to any leafy branch, the nesting bough or twig is cut off, carefully taken down, carried to a convenient spot where there is

good light, and firmly fastened to stakes driven into the ground. The change is one of space relations which may change with every passing breeze, and though it may be of little significance to the birds it is of

FIG. 2. CEDAR-BIRD, APPROACHING NEST WITH GULLET STUFFED WITH CHERRIES PREPARED TO FEED YOUNG BY REGURGITATION.

the utmost importance to the observer, since the nest now is but four instead of forty or more feet from the ground, and the screen of foliage which hid it from view has been withdrawn.

For an observatory I have adopted a green tent which conceals the student with his camera. The tent is pitched beside the nest, and when in use is open only at one point, marked by a small square window in line with the photographic lens and the nest.

By taking such liberties with wild birds, one might suppose we should bring destruction upon their homes and all that they contain,

but happily this is not the case. No harm need befall either old or young. The former nesting site is soon forgotten, and the new quickly adopted and defended with all the boldness and persistence of which the birds are capable.

This method of studying birds thus depends mainly upon the strength of the parental instincts, and upon the readiness with which a bird learns to adapt itself to new conditions. Upon more complete analysis we recognize the following psychological principles, of which the following are the most important: (a) The strength of an instinct increases through its exercise, and may be reinforced by habit; (b) An

FIG. 3. FEMALE KINGBIRD, ASTRIDE NEST, SHIELDING HER YOUNG FROM THE HEAT.

instinctive impulse may be blocked or suppressed by any contrary impulse; (c) The instinct of fear is often quickly suppressed by repetition, or the formation of new habits. One might also add that: (d) New habits are readily formed and may replace the old ones; (e) Abstract ideas, if they form any part of the furniture of the average bird-mind, are extremely hazy and fleeting; (f) Still further we must recall the physiological fact that birds are guided in most of their operations by sight and hearing, not by scent. Their olfactory organ is very rudimentary at best, and avails them neither in finding food nor in avoiding enemies.

Let us see how these principles are applied to the problem of approaching wild birds in the way described. The parental instincts begin to control the life of the adult with the periodic revival of the reproductive functions, and may vary greatly in their scope and intensity. As a rule this instinct, reïnforced by habit, gradually increases until the young are reared. It is, therefore, safest to change the nesting surroundings when the parental instincts are approaching their culmination.

The general feeling of fear is gradually or quickly suppressed

FIG. 4. KINGBIRDS, BRUISING A DRAGON-FLY BETWEEN THEIR BILLS, AND PREPARING TO SERVE IT TO THE YOUNG. THE FEMALE, WHO WAS BROODING WHEN THE PREY WAS CAUGHT, STANDS AT THE FRONT.

according to the value of the different factors in the equation, by the parental instinct, which impels a bird at all hazards to go to its young wherever placed.

After a bird once visits the nest in its new position it returns again and again, and in proportion as its visits to the old nesting place diminish and finally cease, its approaches to the new position become more frequent, until a new habit has been formed, or, if you will, until the old habit is reinstated.

When the birds approach the nest any strange object, like the stakes which support the bough or the tent which is pitched beside it,

arouses their sense of fear and suspicion, and they may keep away for a time or advance with caution. If very shy, like most catbirds, they will sometimes skirmish about the tent for two hours or more before touching the nest. The ice is usually broken, however, in from twenty minutes to an hour, and I have known a chipping sparrow and red-eyed vireo to feed their young in three minutes after the tent was in place.

At every approach the birds see the same objects which work them

FIG. 5. FEMALE ROBIN CLEANING THE NEST.

no ill. The tent stands silent and motionless, but the young are close by, and fear of the new objects gradually wears away. Parental instinct, or in this case maternal love, for the instinct to cherish the young is usually stronger in the mother, wins the day. The mother bird comes to the nest and feeds her clamoring brood. The spell is broken; she comes again. The male also approaches, and their visits are thereafter repeated.

Possibly the fears of the old birds are renewed at sight of the

window, which is now open in the tent-front, and of the glass eye of the camera gleaming through it, but the lens is also silent and motionless, and soon becomes a familiar object to be finally disregarded. Again there is the fear which the sound of the shutter, a sharp metallic *click*, at first inspires, unless you are the fortunate possessor of an absolutely silent and rapid shutter. At its first report, when two feet away, many birds will jump as if shot, give an angry scream, and even fly at the tent as if to exorcise an evil spirit, while after a few hours they will only wince; finally they will not budge a feather at this or any

FIG. 6. THE BROWN THRUSH, STANDING ON HIS NEST, HAS HEARD AN UNUSUAL SOUND AND IS LISTENING INTENTLY.

other often repeated sound, whether from shutter, steam whistle, locomotive or the human voice.

It is the young, the *young, always the young* in whom the interest of the old birds is centered, and about whom their lives revolve. They

are the strong lure, the talisman, the magnet to which the parent is irresistibly drawn. The tree, the branch, the nest itself, what are these in comparison with the young for whom only they exist? This is true notwithstanding the fact that birds will sometimes leave their young to perish while they start on their migrations. As a rule they follow one line of conduct until their instinct in this direction has been satisfied.

With some species it is possible to make the necessary change without evil consequences when there are eggs in the nest: with others we must wait until the young are from four to nine days old. It is all a question of the strength of the parental instinct, and this varies between wide limits in different species, and very considerably between different individuals. From the nature of the case there can be no infallible rule. If we know little of the habits of the bird in question, it is safest to wait until the seventh to the ninth day after hatching, or when, as in many of the common passerine birds, the feather-shafts of the wing-quills begin to appear, or, better, when they project from one-quarter to one-half inch beyond the feather-tubes. At this period the parental instinct is reaching its maximum, and, what is equally important, the sense of fear has not appeared in the young.

Young birds from one to five days old as a rule cannot stand excessive heat. Even when fed and brooded they will sometimes succumb, and here lies the serious danger to be guarded against. A nest of very young birds well shaded by foliage cannot be safely carried into the direct sunshine of a hot summer's day, hence the importance of beginning operations at the proper time when the weather is suitable, and further of not allowing your enthusiasm to get the better of your judgment.

The young may be handled or fed as much as one wishes, provided they have not acquired the instinct of fear. If you are uncertain as to this, and your aim is to study the nesting habits, it is better to avoid approaching, touching or in any way disturbing the young after the flight-feathers have appeared. The cutting of leaves or twigs which obstruct the light or cast undesirable shadows should be done before this time.

Young birds eight or nine days old stand the heat well, provided they are fed, but on very hot days they should not be allowed to go without food for more than two hours at the longest. Should the parents bring no food during this time, it is better to feed the young in the nest, and to suspend operations until the next day.

The old birds may be expected to come to the nest in from twenty minutes to an hour, when the tent is brought into use immediately after the removal of the nesting bough. It is naturally impossible to predict exactly what will happen until the experiment is tried, since

the personal equation or individuality of the birds themselves is an unknown factor. One thing only is certain: that the parental instinct, reinforced by habit, will win in the end, that it will cast out fear and draw the birds to their young.

III.

I have no desire to anticipate every objection which might be raised against the method, were it possible to do so, but after testing it to the best of my ability with the opportunities of two summers, I am confident of its value and am ready to stand sponsor for it in judicious hands. It is hardly necessary to insist that it is not designed for exhibition purposes, and that its successful practice requires some knowledge, with more patience and time.

An apparently serious objection is likely to occur to the ornithologist, namely, the liability of exposing the birds to new enemies. I feared lest prowling cats should discover the young whose nest and branch had been brought down from the tree-top and set up again in plain sight within easy reach from the ground, but I was happily mistaken. Predacious animals of all kinds seem to avoid such nests, as if they were new devices to entrap or slay them.

As for the weather, barring heat, which must be guarded against in the way described, the nesting bough is more secure when fixed firmly to supports than it could possibly have been before.

The tent not only conceals the observer, but protects his camera, an important consideration, since the prolonged action of the sun is liable to spring a leak in the bellows.

IV.

With note-book in hand you can sit in your tent and see and record everything which transpires at the nest, the mode of approach, the kind of food brought, the varied activities of the old and young, the visits of intruders, their combats with the owners of the nest, the capture of prey which sometimes goes on under your eye. No better position could be chosen for hearing the songs, responsive calls and alarm notes of the birds. You can thus gather materials for an exact and minute history of life at the nest, and of the behavior of birds during this important period. More than this, you can photograph the birds at will, under the most perfect conditions, recording what no naturalist has ever seen, and what no artist could ever hope to portray. The birds come and go close to your eye, but unconscious of being observed.

I have watched the night hawk feed her chick with fireflies when barely fifteen inches from my hand, the kingfisher carrying live fish to its brood whose muffled rattles issued from their subterranean gallery a few feet away. When near enough to count her respirations accurately, I have seen the redwing blackbird leave her nest on a hot

day, hop down to the cool water of the swamp, and after taking a sip, bathe in full view, within reach of the hand; then, shaking the water from her plumage, she would return refreshed to her nest. I have seen the male kingbird come to his nesting bough with feathers drenched from his mid-day bath in the river, the orioles flash their brilliant colors all day long before the eye, and chestnut-sided warblers become so tame after several days that the female would allow you to approach and stroke her back with the hand.

It is difficult to describe the fascination which this method of study affords the student of animal life. New discoveries or unexpected sights wait on the minutes, for while there is a well-ordered routine in the actions of many birds, the most charming pictures occur at odd moments, and there is an endless variety of detail. It is like a succession of scenes in a drama, only this is real life, not an imitation, and there is no need of introducing tragedy.

A STUDY OF BRITISH GENIUS.

By HAVELOCK ELLIS.

VI. MARRIAGE AND FAMILY.

THE tendency to celibacy among men of preeminent intellectual ability has frequently been emphasized by Lombroso and others. It is well illustrated by British men of genius. We may probably assume that by the age of fifty scarcely more than 10 per cent. of the male population remain bachelors, if we take the whole population into consideration. (This is the case in Hungary, and it can not be very far from the truth, so far as Great Britain is concerned.) It is true that, as Kórösi and others have shown, among the well-to-do classes men marry both later and seldomer, and that the subjects under consideration largely belong to those classes. We can, however, well afford to leave a margin on this account. We have information concerning the status as regards marriage of 819 of the preeminent men in our list; of these, seventy-two, being Catholic priests or monks (ten of them since the Reformation), were vowed celibates, and 160 others never married. We thus find that 28 per cent. never married, and even if we exclude the vowed celibates, 21 per cent. It must, of course, be remembered that a certain, though not considerable, proportion of the unmarried were under fifty at death, and some of these would certainly have married had they survived. It may be added that about two-thirds of the women were married, though several of those (especially actresses) belonging to the unmarried third formed *liaisons* of a more or less public character, and in a few cases had several children.

It must not be supposed that all these eminent men who lived long lives in celibacy were always so absorbed in intellectual pursuits that the idea of matrimony never occurred to them. This was not always the case. Thus we are told of Dalton, that the idea had crossed his mind, but he put it aside because, he said, he 'never had time.' In several cases, as in that of Cowley, the eminent man appears really to have been in love, but was too shy to avow this fact to the object of his affections. Reynolds is supposed only once to have been in love, with Angelica Kauffmann; the lady waited long and patiently for a declaration, but none arrived, and she finally married another; Reynolds does not appear to have been overmuch distressed, and they remained good friends. These cases seem to be fairly typical of a certain group of the celibates in our list; a passionate devotion to intellectual pursuits seems often to be associated with a lack of passion

in the ordinary relationships of life, while excessive shyness really betrays also a feebleness of the emotional impulse. Even in many cases in which marriage occurs, it is often easy to see that the relationship was rooted in the man's intellectual passion.*

The average age of marriage among the men in our list, taking one hundred cases, is found to be thirty-one years, the most frequent age being from twenty-eight to thirty-two inclusive. Of these, four were under twenty, and thirteen over forty at the date of their first marriage. This proportion of late marriages is abnormally high, especially when we remember that the marriages of widowers are here excluded. The proportion of early marriages is somewhat low, as compared with the general population in England to-day. The average age, thirty-one years, is distinctly late, more especially when we remember that it only includes first marriages. The average age of marriage for all males during recent years in England is between twenty-eight and twenty-nine years, and at the other side of the world, in New Zealand, though later, it is still below thirty. The most frequent age of marriage also falls much earlier. In estimating the significance of these figures as regards men of genius, we have to remember, on the one hand, that the well-to-do classes, to which men of preeminent intellectual ability largely belong, marry later than the general population, and, on the other hand, that the general tendency to marry late is of recent growth. If we are entitled to believe that these conflicting tendencies balance each other, the data still indicate that British men of genius have shown a tendency not only to marry seldom, but to marry late.

The married women on our list form too small a group to generalize about with safety. One notable fact, however, emerges. They show a tendency to marry either before or after the period at which the majority of married women marry, but not during that period. In England during recent years the average age at which women marry has been about twenty-six years. But among British women of genius very few marriages take place during the period of great reproductive energy; the large majority of such marriages fall outside the period between twenty-three and thirty-four years of age. In the majority of cases marriage took place before this period, the relationship, from one reason or another, being very often dissolved not long afterwards; but in a very considerable proportion of cases, marriage never took

* Dr. P. Garnier ('Célibat et Célibataires,' pp. 72-5) has some interesting remarks on this point. He considers that genius is, or should be, celibate, and that a man of genius is not usually able to make a woman's life happy. He mentions that among the eighty-four professors at the medical faculties of Paris, Lyons and Bordeaux—the three chief medical centers of France—fifteen are celibates, and of the sixty-nine who are married eleven are childless.

place until after this period. Thus, Fanny Burney married at forty-one, Mrs. Browning at forty, Charlotte Brontë at thirty-eight, while George Eliot's relationship with Lewes was formed at about the age of thirty-six; these names include the most eminent English women of letters. It would thus appear that there is a tendency for the years of greatest reproductive activity to be reserved for intellectual development, by accelerating or retarding the disturbing emotional and practical influences of real life. This tendency might still be beneficial, even when the best work was not actually accomplished until after a late marriage.

We have now to consider the fertility of the marriages formed by men of preeminent intellectual ability. Lombroso and others have insisted on the tendency to sterility among men of genius, but have always been content merely to cite a few cases in proof. This method can at the most raise merely a presumption in favor of the dictum laid down. The present investigation, covering a very large group of men of the highest intellectual eminence, furnishes more conclusive evidence as to the actual facts. It confirms only to a limited extent the belief in the relative sterility of men of genius, though we have to remember the very high mean age of the individuals we are considering. The married men of intellectual ability in our list number 587; of these, 448 had children; seventy-six are definitely stated by the national biographer not to have had children; sixty-three cases remain in which the point is passed without mention, or in which it is stated that the marriage was not fruitful, but that there were illegitimate children. It appears, so far as I can judge, that in the majority of the sixty-three doubtful cases, there were really no legitimate children; this has most often been found to be the case when I have checked the national biographer by other sources of information. In a certain proportion of cases, however, the facts regarding children are not known, and in others the children have apparently been ignored. We may probably conclude that nearly two-thirds of these sixty-three doubtful cases were really unfruitful. (I may add that, even if we exclude the doubtful cases altogether, the proportion of unfruitful marriages remains very abnormally large.) We then find that about 20 per cent. of the marriages of British men of genius have been unfruitful. In this case we have not much difficulty in obtaining a normal standard of comparison. Karl Pearson, manipulating the data furnished by Howard Collins, has found that during the past century among the middle and upper classes chiefly of British race, or belonging to the United States —a class fairly comparable to those in the present group—the total sterility is about 12 or 13 per cent., rather less than half of this (*i. e.*, about 6 per cent.) being due to what is termed 'natural sterility'; while the remainder (*i. e.*, 6 or 7 per cent.) must be set down to artificial restraints on reproduction. If, again, we turn to New Zealand, where

the methods of death registration enable us to form an approximate estimate of the proportion of childless marriages among the whole population of somewhat mixed British race, with a high standard of living, we find that the proportion of marriages in which there are no surviving children at the father's death is about 16 per cent. With due allowance for the earlier death of the children and for the ignorance, in a certain proportion of cases, of those who filled in the death certificate, it is probable enough that this result is not really larger than the other. In any case there is an excess of sterility among the group of intellectually eminent men, this excess being the more marked when we remember that in very large majority they belong to a period when the artificial restraint of reproduction had scarcely begun to be widely practiced.

It is somewhat remarkable that, although the number of infertile marriages is so large, the average fertility of those marriages which were not barren is by no means small. We have fairly adequate information in the case of the marriages of 214 of these eminent men. I have not included those cases in which the national biographer is only able to say that there were 'at least' so many children, nor have I knowingly included any cases in which there were two or more marriages. Whether the number of children represents gross or net fertility, it is, unfortunately, in a very large proportion of instances, quite impossible to say. It is probable that in a large proportion of cases only the net fertility, *i. e.*, the number of children who survived infancy and childhood, has been recorded. It is, therefore, the more remarkable that the average number of children in these 214 fertile families is 5.45. Thus, although our data are probably imperfect, they show that the fertile marriages of British men of genius have produced families which contain on the average one child more than the fertile marriages of ordinary people of the same race during the nineteenth century; in New Zealand the average number of children left by fathers of families (whether as the result of one or more marriages) dying between the ages of twenty-five and sixty-five, is 4.81, which indicates a much larger gross fertility. It must, of course, be remembered, on the other hand, that the eminent men in our group lived to a very high average age, and it is obvious that men who live to an advanced age will have a better chance of leaving large families than those who die young.* This consideration somewhat diminishes our estimate of the fertility shown by British men of genius, while, if we take barren marriages into

* Even apart from this, there appears to be a connection between longevity and fecundity; see M. Beeton and Karl Pearson, 'On the Correlation between Duration of Life and the Number of Offspring,' a paper presented to the Royal Society of London, June 14, 1900.

account, the fertility is greatly pulled down, but still remains well up to the average. This normal average is thus attained by a conjunction of an abnormal proportion of sterile marriages, together with an abnormally high proportion of children among the fertile marriages.

There would appear to be a considerable resemblance between the fertility of genius families and of insane families. We have seen previously that our eminent British persons belonged to families of probably more than average fertility; we now see that they themselves produced families of probably not more than average size, owing to a greater prevalence of sterility. In France, Ball and Régis, confirmed by Marandon de Montyel, appear to have found reason for a similar conclusion regarding the insane. They state that natality is greater among the ascendants of the insane than in normal families, but afterwards it is the same as in normal families, while they also note the prevalence of sterility in the families of the insane.* The question, however, needs further investigation.

With regard to the distribution of families of different sizes, the results, as compared with the figures already given, are as follows:

Size of Family	1	2	3	4	5	6	7	8
Normal Families	12.2	14.7	15.3	14.1	11.1	8.6	7.8	6.3
Genius-producing Families	6.2	6.2	11.0	8.4	10.6	10.2	11.7	6.9
Families of Men of Genius	12.6	14.5	10.3	13.6	8.8	6.5	10.3	4.7

Size of Family	9	10	11	12	13	14	over 14
Normal Families	3.9	2.7	1.4	1.0	.5	.2	.1
Genius-producing Families	5.5	4.4	5.8	4.0	2.9	1.8	4.0
Families of Men of Genius	5.1	2.8	3.2	.9	2.3	1.4	2.3

Allowing for certain irregularities due to the insufficient number of cases, the interesting point that emerges is the return towards the proportions that prevail in normal families; it will be seen that in all but a few cases the families of men of genius differ from genius-producing families by approximating to normal families. It must be remembered that in neither of our groups are the data absolutely perfect, but as they stand they confirm the conclusion already suggested that men of genius belong to families in which there is a high birth-rate, a flaring up of procreative activity, which in the men of genius themselves subsides towards normal proportions. The slightly larger average size of the families of men of genius as compared with normal families is merely due to the presence of a few families of excessively large size.

* See, for a summary of these results, Toulouse, 'Les Causes de la Folie,' p. 91; 1896.

It will be noticed that the families of sizes ranging between three and six, both inclusive, are unduly few. It might be supposed that this is due to the artificial limitation of families, more especially since, as Karl Pearson has pointed out, in the normal families themselves there is already a deficiency in those groups, probably due to this cause. I am, however, inclined to doubt whether that is so in the case of families of men of genius, although to some extent it may be so. There seems some reason to suppose that from the present point of view the group may not be homogeneous, but made up in part of men with feeble vitality and a tendency to sterility, and in part of men with a tendency towards unusual fecundity, thus leading to a deficiency of medium-sized families.

In the case of 147 families of men of genius, it has been possible to ascertain the number of children of each sex. This is found to be 100 girls to nearly 103 boys. This is almost the normal proportion of the sexes at birth at the present time in England. If, however, I am right in supposing that in a certain proportion of our cases the biographers have stated not the gross fertility, but only the net fertility (or the surviving children), we are not entitled to expect so close an approximation to the proportions at birth, since the preponderance of boys begins to vanish immediately after birth. The figures thus suggest that the families of men of genius show the same tendency to excess of boys, which we have already seen to be clearly marked in the case of the families producing men of genius. The data are too few to indicate whether there is any corresponding excess of girls in the families of women of genius.

VII. DURATION OF LIFE.

IT has long been a favorite occupation of popular writers on genius to estimate the ages at which famous men have died, to dilate on their tendency to longevity, and to conclude, or assume, that longevity is the natural result of a life devoted to intellectual avocations. The average age for different groups, found by a number of different inquirers, varies between sixty-four and seventy-one years. One writer, who finds this highest age for certain groups of eminent men of the nineteenth century, argues that here we have a test from which there is no appeal, proving the preeminence of the nineteenth century over previous centuries, and its freedom from 'degeneration.' It did not occur to this inquirer to ask at what age the famous men of earlier centuries died. I have done so in the case of a small group of ten eminent men on my list, dying between the fourth and the end of the thirteenth centuries—including, I believe, nearly all those in my list of whose dates we have fairly definite information during this period —and I find that their average age is exactly seventy-four years. So

that, if this test means anything at all, the freedom of the nineteenth century from 'degeneration' is by no means proved.

In reality, however, it means nothing. If genius were recognizable at birth there would be some interest in tracing the course of its death-rate. But it must always be remembered that when we are dealing with men of genius, we are really dealing with *famous* men of genius, and that though genius may be born, fame is made—in most fields very slowly made. Among poets, it has generally been found, longevity is less marked than among other groups of eminent men, and the reason is simple. The qualities that the poet requires often develop early; his art is a comparatively easy one to acquire and exercise, while its products are imperishable and of so widely appreciated a character that even a few lines may serve to gain immortality. The case of the poet is, therefore, somewhat exceptional, though even among poets only a few attain perfection at an early age. In nearly every other field the man of genius must necessarily take a long period to acquire the full possession of his powers, and a still longer period to impress his fellowmen with the sense of his powers, thus attaining eminence. In the case of the lawyer, for instance, the path of success is hemmed in by tradition and routine, every triumph is only witnessed by a small number of persons, and passes away without adequate record; only by a long succession of achievements through many years can the lawyer hope to acquire the fame necessary for supreme eminence, and it is not surprising that of the thirty-four preeminent lawyers on my list only four were under sixty at death. Much the same is true, though in a slightly less marked degree, of statesmen, divines and actors.

It is, therefore, somewhat an idle task to pile up records of the longevity of eminent men of genius. They live a long time for the excellent reason that they must live a long time or they will never become eminent. It is doubtless true that men of genius—mostly belonging to the well-to-do classes, and possessing the energy and usually the opportunities necessary to follow intellectual ends of a comparatively impersonal and disinterested character—are in a far more favorable position for living to an advanced age than the crowds who struggle more or less desperately for the gratification of personal greeds and ambitions, which neither in the pursuit nor the attainment are conducive to peaceful and wholesome living. This may well be believed, but it is hardly demonstrated by the longevity of eminent men.

At the same time it is of some interest to note the ages of the eminent persons on our list at death. Though the facts may have little significance in themselves, they have a bearing on many of the other data here recorded. Excluding women, and including only those men whose dates are considered by the national biographers to be unquestionable, the ages of eminent British men at death range from Chatter-

ton, the poet, at seventeen, to Bishop Morton, the scholar (born in the seventeenth century), and Sir Edward Sabine, the man of science (born in the eighteenth century), at ninety-five. They are distributed as follows in five-year age-periods:

Age at Death...	Under 20	20–24	25–29	30–34	35–39	40–44	45–49	50–54
Men of Genius..	1	2	5	13	13	29	48	51
Age at Death.	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90 and over
Men of Genius	66	84	108	116	86	49	35	14

If we consider the number for each year separately, certain points emerge which are disguised by the five-year age-period, though the irregularities become frequently marked and inexplicable. A certain order, however, seems to be maintained. There is scarcely any rise from twenty-seven to thirty-eight, and even at forty-five only three individuals died; but, on the whole, there is a slow rise after thirty-eight, leading to the first climax at forty-nine, when sixteen individuals died; this climax is maintained at a lower level to fifty-four, when there is a marked fall to a level scarcely higher than that which prevailed between the ages of forty-one and forty-three. This lasts for three years; then there is a sudden rise from seven deaths at fifty-six, to twenty-five deaths at fifty-seven, and this second climax is again maintained at a somewhat lower level to the age of sixty-seven, when the highest climax is attained, with thirty-one deaths. Thereafter the decline is slow but steady, with a final climax of twenty deaths at seventy-eight. It is curious that each climax is sudden, and preceded by a fall.

A noteworthy point here seems to be the very low mortality between the ages of fifty-three and fifty-seven. It seems to confirm Galton's conclusion, based on somewhat similar data, that a group of men of genius is in part made up of persons of unusually feeble constitutions and in part of persons of unusually vigorous constitutions. After the first climax at forty-nine the feeble have mostly died out. The vigorous are then in possession of their best powers and working at full pressure; fifty-seven appears to be a critical age at which exhaustion and collapse are specially liable to occur. The presence of these two classes—the abnormally weak and the abnormally vigorous —would be in harmony with the explanation I have already ventured to offer of the deficiency of medium-sized families left by our men of genius.

The age of the women is ascertainable in thirty-nine cases. The average is extremely high; four died before forty, but nine lived to over eighty, and two of these were over ninety.

THE PROGRESS OF SCIENCE.

THE NATIONAL ACADEMY AND OTHER SCIENTIFIC SOCIETIES.

THE annual stated meeting of the National Academy of Sciences was held in Washington in the third week in April. Professor Wolcott Gibbs, one of the two surviving founders of the Academy and the distinguished dean of American men of science, having resigned the presidency a year ago, Mr. Alexander Agassiz, of Cambridge, was elected to the office. It may almost be said that Mr. Agassiz assumed the presidency by right, as he exactly represents the hereditary distinction and aristocratic preeminence of a small and select National Academy. It is possible that such an institution belongs to the past rather than to the democracy of the twentieth century, but there is perhaps less danger in America from the preservation of precedents than from their abolition. Mr. Asaph Hall remains vice-president and Mr. Charles D. Walcott treasurer of the Academy, while the vacancy in the foreign secretaryship, caused by Mr. Agassiz's elevation to the presidency, was filled by the election of Prof. Ira Remsen, whose former office of home secretary is now occupied by Mr. Arnold Hague. Five new members were elected: George F. Becker, U. S. Geological Survey, Washington, D. C.; J. McKeen Cattell, professor of psychology, Columbia University, New York City; Eliakim H. Moore, professor of mathematics, University of Chicago, Chicago, Ill.; Edward L. Nichols, professor of physics, Cornell University, Ithaca, N. Y., and T. Mitchell Prudden, professor of pathology, College of Physicians and Surgeons, Columbia University. An improvement has recently been made in the manner of election to the Academy. The members have been divided into six standing committees, and a nomi-

nee must be endorsed by the committee having an expert knowledge of his qual-

having an expert knowledge of his qual-

1899 only thirteen new members were elected, although twenty-seven vacancies occurred through death, whereas during the past three years fourteen new members have been elected. Eight foreign associates were elected: MM. Janssen, Loewy, Bornet and Cornu, of France; Professors Kohlrausch and van't Hoff, of Germany; Professor Kronecker, of Switzerland, and Sir Archibald Geikie, of Great Britain. The Henry Draper medal was awarded to Sir William Huggins, president of the Royal Society, for his investigations in astronomical physics. In the scientific sessions of the Academy eleven papers were presented, as follows:

'The Climatology of the Isthmus of Panama': Henry L. Abbot.

'The Effects of Secular Cooling and Meteoric Dust on the Length of the Terrestrial Day': R. S. Woodward.

'The Use of Formulæ in demonstrating Relations of the Life History of an Individual to the Evolution of its Group': Alpheus Hyatt.

'Artificial Parthenogenesis and its Relation to Normal Fertilization': E. B. Wilson.

'Simultaneous Volumetric and Electric Graduation of the Condensation Tube': Carl Barus.

'Table of Results of an Experimental Enquiry regarding the Nutritive Action of Alcohol, prepared by Prof. W. O. Atwater, of Middletown, Conn.': Presented by J. S. Billings.

'The Significance of the Dissimilar Limbs of the Ornithopodous Dinosaurs': Theo. Gill.

'The Place of Mind in Nature,' 'The Foundation of Mind': J. W. Powell.

'Conditions Affecting the Fertility of Sheep and the Sex of their Offspring': Alexander Graham Bell.

'The New Spectrum': S. P. Langley.

DURING the same week that our National Academy was meeting at Washington, the recently established Interna-

tional Association of Academies was holding its first regular session at Paris. This association was organized at Wiesbaden two years ago and held a preliminary meeting at Paris last year. It is composed of representatives of the great academies of the world—eighteen in all—and includes in its scope literature as well as science. The object of the Association is to promote international cooperation in scientific work; it represents a movement the importance of which is very great and the accomplishment of which is very difficult. It is probable that a more representative congress would better forward the ends in view, but it may be that such a congress can best be developed by beginning with a small meeting of eminent men. There seems, however, to be good reason to protest against the star chamber methods which the Association seems inclined to adopt. We are told of a dinner given by the municipal council of Paris, a reception by the president of the French Republic and a theatrical performance at the Comédie Française, but not the slightest information can be obtained regarding the secret sessions of the Academy, at which scientific plans were presumably considered. Questions to be taken up should be announced well in advance, and they should be carefully considered by scientific men and discussed in the scientific press. M. Darboux was acting-president for the meeting, and the honorary presidents were Dr. Mommsen, Dr. de Goeje, Sir Michael Foster, M. Berthelot and M. Gaston Boissier. We regret to learn that the delegate from the National Academy of Sciences, Prof. G. L. Goodale, was detained by illness at Geneva; otherwise all the academies were represented. The next meeting will be in London in 1904.

THE Council of the American Association for the Advancement of Science held its spring meeting at Washington at the time of the sessions of the National Academy of Sciences. The report made by the permanent secretary was very gratifying. Over seven hundred new members have been elected within the past year; the membership is now larger than ever before and includes almost the whole body of scientific workers in this country. The sum of $1,300 has been saved from current receipts and turned over to the permanent fund for the encouragement of research. The arrangement by which the weekly journal 'Science' is sent free of charge to members is apparently giving perfect satisfaction and is helping the Association in many ways. Progress has been made towards securing an agreement among universities and other institutions to set aside a week after the Christmas holidays for the meetings of scientific and learned societies. The plan was unanimously approved by the Association of American Universities, and Columbia and Cornell have already taken action lengthening their vacations for this purpose. Progress was reported in the arrangements for the Denver meeting, a single fare on the railways west of Chicago having been secured. The meeting, the first to be held so far toward the West, promises to be of unusual importance. Readers of this journal who are not members of the Association may obtain information as to the conditions of membership by addressing the permanent secretary, Dr. L. O. Howard, the Cosmos Club, Washington, D. C.

THE HARVARD COLLEGE OBSERVATORY.

THE fifty-fourth annual report of the director of the Harvard College Observatory gives a clear idea of the activity which prevails at that institution. As the present year marks the beginning of a new century, Professor Pickering finds the time opportune for describing the present condition and needs of the Observatory. As stated in the previous annual report, the invested funds amount to something over $800,000. The annual income is about $50,000, but, owing to the continued diminution

in the rate of interest on invested property, the income will steadily decrease unless an additional sum is obtained. Two hundred thousand dollars more are needed to place the institution in such a condition that its standing among the great observatories of the world shall be secure. The buildings at Cambridge are old and to provide new ones, suited to modern requirements, will cost at least $100,000. The present buildings at Cambridge are valued at $52,000 and at Arequipa $12,000. The instruments at Cambridge are valued at $20,000 and at Arequipa $50,000. The great need of the Observatory in the instrumental way is a great telescope for the southern hemisphere, the cost of which, for construction and maintenance, would be about $200,000. Altogether, half a million dollars are desired to make the Observatory worthy of the great future which opens before it. More money is also needed for publication. Already there have been issued by the Observatory about forty quarto volumes of the 'Annals,' embracing researches in many lines of astronomy and meteorology. An enormous amount of material, however, is still awaiting publication, sufficient to make about twenty-eight additional volumes. Some of these will be issued soon, and all as rapidly as the nature of the work and the funds available for publication will permit.

During the last year several lines of investigation have been pursued. Photometric and photographic determinations were made of the brightness of a great number of stars, including several hundred variables. The reduction of the observations of the zones made in former years with the meridian circle has been carried forward. As usual, the whole sky was photographed several times on a small scale. These photographic charts have proved of the greatest value in tracing the past history of new stars, variable stars and special new objects, such as the little planet Eros. Also a very large number of photographs have been made of special objects with instruments of greater power. Progress was made in the study of the spectra of the stars and several objects of special interest were discovered, including one nova. Intimately associated with the institution is the Blue Hill Meteorological Observatory—where during the year some striking experiments were carried on in kiteflying. A meteorgraph, suspended under the kite, gave records at heights as great as 15,800 feet above sea level. In Peru, the line of meteorological stations extending from the Pacific across the Andes, with one on the summit of El Misti, at an elevation of 19,200 feet, has been maintained. The Harvard Observatory acts as the distributing center in this country for all telegraphic announcements of astronomical discoveries. During the year twenty messages were sent out to American and European astronomers.

THE NEW YORK BOTANICAL GARDEN.

THE advance sheets of the 'Bulletin' of the New York Botanical Garden for 1901, and the pages of the 'Journal,' show most gratifying progress in that institution since the preparation of the article dealing with it published in this magazine in June of last year. About seven thousand species of plants are now successfully cultivated in the open air and under glass. The large conservatories, which were completed in 1900, have been filled by plants received as gifts and as exchanges. Many donations of great value have been received from various persons, and notable exchanges have been made with the Buffalo Botanic Garden and Fairmount Park. A collection of succulents, numbering about five hundred species, purchased by Dr. N. L. Britton during his recent European tour in attendance at the International Congress of Botanists in Paris, has been recently received and is now installed in the conservatories. Mr. Samuel Henshaw resigned from the position of head gardener on January 1, 1901, and was sent on a collecting tour in the West Indies. He has recently re-

turned with valuable material from Trinidad and Jamaica. Mr. George V. Nash, who was promoted from the position of curator of the plantations to the place of head gardener, spent February and March at the Royal Gardens, Kew, by special invitation, for the purpose of selecting from the duplicates of the immense collections of living plants. About two thousand species were secured, the greater number of which promise to thrive, and form the most valuable single addition yet made to the flora of the Garden. Mr. Percy Wilson, museum aid, was sent with the Amherst Astronomical Expedition to Sumatra in March and will spend about six months in that region securing specimens for the economic museum and living plants for the horticultural houses. Other explorations are projected for the present season.

A set of propagating houses was erected at a cost of $16,000 in the latter part of 1900, some new road and pathways built to it, and other ground improvements made. The New York Central and Hudson River Railroad has completed a station on the margin of the grounds, which enhances the beauty of one of the principal approaches to the Museum. Contracts aggregating nearly $200,000 have been let for the present season, embracing the completion of the main horticultural houses, main approaches and grounds in front of the Museum, fountains, roadways and areas round and near both buildings. The income of the Garden from all sources amounts to over $75,000 for 1901. The library was increased by over fifteen hundred volumes and a large number of separates during the year 1900. The herbarium received additions amounting to about seventy thousand specimens, inclusive of the Morong Herbarium of Barnard College, which is deposited under the same conditions as that of Columbia College. Dr. T. F. Allen, the noted specialist on the Characeæ, has recently given his collection of that group to the Garden without reserve, and it is now in process of arrangement under Dr. Allen's supervision. The economic museums have been filled out in many important particulars, but remain in a skeleton state, as a number of years will be necessary to make an adequate representation of many of the subjects taken up. The exhibition microscopes installed a year ago have been objects of great interest and profit to visitors.

The laboratories have accommodated twenty-eight investigators during the year, and the results of some of their researches have been published as contributions, or are being offered as theses, by candidates for degrees at various universities. These investigations extend over the entire range of botany. The equipment has been steadily increased to meet the varied needs of these workers, and the experimental greenhouses afford valuable supplemental facilities in such work. In addition to these original researches, Dr. N. L. Britton has finished a 'Manual of the Plants of Eastern United States,' which is being published by the Henry Holt Company, and Dr. D. T. MacDougal has written an advanced text-book of 'Practical Plant Physiology,' published by Longmans, Green & Co. Seventeen popular lectures were given in the lecture hall of the Museum in the winter of 1900-1901, which were attended by one to five hundred people. The annual meeting of the Horticultural Society of New York was held at the Garden, May 8 and 9, 1901, and the exhibition was notably successful.

THE PRACTICAL APPLICATIONS OF ELECTRICITY.

IN the *Electrical World and Engineer* for January 5, 1901, the first number of the twentieth century, appeared a series of articles on the past progress of applied electricity and upon its prospects for the future. Among the authors are some of the most prominent of American electricians, such as Elihu Thomson, A. E. Kennelly, Louis Bell, Kempster B. Miller, Carl Hering, H. Ward Leonard, Patrick B. Delany, and some of the

more prominent men in science. The various papers are quite largely devoted to statements of the unsolved practical and theoretical problems, in so far as they are capable of statement.

In the line of theory and research the most promising field seems to be the development of the *electron theory* which has been in the past mainly built up on experimental studies of the electrical discharge in gases. This theory is an attempt to represent all electrical phenomena in terms of the conception of the *electron*, an excessively minute charged particle, a thousand times smaller than an atom. This theory has already given a remarkably clear insight into the electrical properties of gases, and tentative explanations of the most promising kind of the ultimate constitution of matter, and of the nature of gravitation, two of the most stupendous problems of the present day in physics.

Among the purely practical problems, purely practical because the scientist has, one might almost say, given it up in despair, is the production of electrical energy direct from coal. One can say almost to a certainty that if one is to transform a large percentage of the latent energy of coal into electrical energy the coal *must not be burned*. The mischievous waste at present endured seems to be inherent in the burning process, but the wildest dreamer has never imagined that coal can be of any use other than for feeding a fire! There does seem to be a difficulty here, and perhaps the example of the scientist who revels in thermodynamics might just as well be followed by the inventive practical man. One thing, however, is certain and that is that the solution of this problem depends upon the invention of a new kind of fire which can be stopped in mid air, as it were, by a turn of the hand, each atom of carbon and each atom of oxygen stopping its mad whirl to begin it again at our pleasure, standing in the meantime in a state of quiet expectancy. Such a fire the physicist would call a *reversible* fire. The burning of zinc in a voltaic cell is indeed such a fire, and most of the attempts to transform the latent energy of coal into electrical energy efficiently have been attempts to construct a voltaic cell which will burn coal. Another kind of reversible fire might be realized in the gas engine if we had materials, to build a gas engine of, which would stand excessively high temperatures and excessively high pressures. In such a gas engine a mixture of gas and air could be enormously compressed and made so hot that it could not burn, then by expanding the mixture combustion would slowly take place and in such a way that to stop expanding would be to stop the combustion. Such combustion would be reversible, for to recompress the mixture would literally unburn it. Such a gas engine would have a very high efficiency if one could keep the cylinder from being cooled by the surrounding air.

The burning of food in the body of a work horse is a case in which an unusually large percentage of the latent energy of the fuel, or food, is converted into useful work, and thermodynamics tells us beyond peradventure that this high efficiency must be due to a state of affairs something like the following: Let us imagine the muscles built up of enormously complicated molecules, like the molecules of albumin for example, and let us imagine that as a muscle contracts these complicated molecules are distorted slowly, and that as they become distorted some of the atoms of carbon and hydrogen are slowly bulged out of the molecular structure and gingerly allowed to approach the atoms of oxygen in the blood in such a way that the process would be arrested at any moment by a cessation of the contraction. If such a process could be completely realized and if the atoms of oxygen could also be kept at bay by being themselves involved in some fashion in the bulging process of the muscular structure, then the efficiency of muscular action would be one hundred per cent. It is in fact much less

than one hundred per cent., on account, perhaps, of the oxygen molecules being unbridled.

THE WISCONSIN AGRICULTURAL EXPERIMENT STATION.

THE seventh annual report of the Wisconsin Agricultural Experiment Station is a notable example of a class of literature which is rapidly increasing in extent and in popular interest. The reports of this station have become widely known for the important contributions which they contain and for their interest to those who follow the progress of science, as well as to the progressive farmer, whose needs are kept constantly in view. The last report, which is for the year ending June 30, 1900, is fully up to the standard of previous reports. It adds another chapter to the interesting studies on the process of cheese ripening or curing which Dr. Babcock and Dr. Russell have been conducting for a number of years. In the past their studies have led to the discovery of a natural enzym in milk which has been shown to be an active agent in the digestion of the proteids of cheese, rendering them soluble and digestible. This discovery, which was contrary to the prevalent bacterial theory and was opposed by many bacteriologists, has stood the test, and the theory is now generally believed in, the main point at issue being the extent and the exact character of the changes which the ferment induces. The present report takes up the action of another ferment in cheese, namely, rennet, which is added during the process of manufacture. There has been much diversity of opinion as to whether the rennet had any part in the ripening process, but very little real investigation. The most recent writings on the subject have disclaimed any action due to rennet. Babcock and Russell now show that rennet undoubtedly assists in peptonizing the casein of cheese, the active agent being the peptic enzyms contained in the rennet extracts. The investigation is a quite comprehensive one, involving a study of the action of pure pepsin as compared with rennet, the conditions of the acidity most favorable to the action, and the nature of the products. The matter is of considerable importance, since it is found that the amount of rennet used influences the rapidity and the thoroughness of the ripening process. The wonder is that a point upon which there has been such marked discrepancy of opinion has not been given a thorough investigation before this.

OF equal interest is the investigation of the cause and character of the changes in green fodder when preserved as silage in the silo, also by Drs. Babcock and Russell. The generally accepted theory of silage formation as fermentation changes, due to the action of bacteria and molds, is found to be erroneous, inasumuch as good silage was made under conditions which positively precluded bacterial activity, i. e., in the presence of anæsthetics. With the aid of an ingeniously-devised closed-circuit respiration apparatus, the authors were able to study the gaseous products and to maintain the conditions entirely under their control. The unavoidable losses in ensiling green fodder were found to be due to the formation of water, carbon dioxid and volatile organic acids, which are produced, not as a result of the bacterial action, but as a result of the intromolecular respiratory processes of the plant tissues. The avoidable losses, on the other hand, are found to be due mainly to the decomposition of organic matter induced by the development of bacteria and molds, whose growth is greatly facilitated by the admission of air, as a result of improper construction of the silo. The bacteria are, therefore, instead of being essential to good silage, only deleterious. In view of the extent to which silage is now prepared in this country, and the fact that the spoiled or partly spoiled silage is not only a loss but is likely to be injurious to stock, these results, which furnish a clearer under-

standing of the factors which enter into the process, cannot fail to be of much practical importance. A study of the thermal death point of tubercle bacilli in milk confirmed the results of the previous year, showing that by using a closed pasteurizer tubercle bacilli can be destroyed by heating milk for twenty minutes at 140° F., instead of at 150-155°, as formerly. This lowering of the necessary temperature removes the objection formerly made that cream does not rise readily on pasteurized milk and that the consistency or body of pasteurized cream is much lessened.

THE soil investigations of the Wisconsin Experiment Station have come to be regarded as one of its most prominent features. In addition to investigations on the soluble salts of cultivated soils, the influence of potash salts on the black marsh soils of the State, which have been exceedingly difficult to manage, Professor King reports studies of the influence of the right amount and the right distribution of water in crop production—a subject upon which information is quite meager and which points directly to the application of irrigation, even in humid climates, to correct insufficient or inadvantageously distributed rainfall. In the horticultural line, Professor Goff has for several years been studying the injury to the buds and roots of fruit trees from cold, and in the present report he gives an illustrated account of his investigations on the time of formation and the development of the flower buds, and also on the resumption of root growth of fruit trees in the spring; and his assistant gives the results of systematic observations on the duration of the growth period in fruit trees. These subjects are closely connected with the management of fruit orchards and will furnish a rational basis for practice. In addition to these lines of investigation, the report also contains accounts of feeding experiments with pigs, sheep and dairy cows, to answer more immediately practical questions; studies of various factors influencing the Babcock milk test, a rapid method for the estimation of salt in butter, a trial of a new kind of churn, operated by forcing a steady stream of air into the cream, for which great claims have been made; studies of the effect of the continued use of immature seeds; studies relating to tannery refuse and hides as causes of the disease in animals known as anthrax; experience with sugar beet culture in Wisconsin, and several other lines.

Altogether, the report is one of surpassing interest, and the results of quite a part of the experiments and investigation will not be confined in their application within the borders of the State. If any indication is needed of the importance of the work being done by the agricultural experiment stations of this country and the wisdom of Congress in continuing liberal appropriations for their work, this report should go a long way in the direction of furnishing such indication.

SCIENTIFIC NEWS.

SCIENCE in America could have suffered no more severe loss than the death of Henry Augustus Rowland, professor of physics in the Johns Hopkins University. Dying at the age of fifty-two years, he was one of the world's most eminent men of genius and one of the two great physicists that America has produced. An account of Rowland's life and work, with a portrait, was published in the POPULAR SCIENCE MONTHLY for May, 1896, and we reproduce in the current number an address given by him some years ago before the American Association for the Advancement of Science.

WE note with regret a number of other recent deaths among men of science, including: Thomas Conrad Porter, the botanist, for the past thirty-four years professor at Lafayette College; John Thomas Duffield, for more than forty years professor of mathematics at Princeton University; Richard T. Rothwell, editor of the 'Engineer-

ing and Mining Journal'; Frederick J. Brockway, assistant demonstrator of anatomy at the College of Physicians and Surgeons of Columbia University; F. M. Raoult, the eminent chemist, professor at Grenoble; Paul Chaix, professor of geography at Geneva; Josef von Fedor, professor of hygiene at Buda Pesth, and Adolph Hirsch, professor of astronomy at Neuchatel. Two men of science lost their lives in the direct pursuit of knowledge: Dr. P. Kohlstock died at Tien-Tsin, while making researches on tropical diseases, and Dr. Menke was murdered by natives while on an exploring expedition to Macquari Island.

THE erection of a memorial to Huxley in Ealing, near London, where he was born and received his early education, is contemplated. A bronze medallion portrait has been advocated for the central feature of the design, which may take the form of a simple mural tablet or of a more worthy monument as funds are obtainable. Subscriptions are not confined to the neighborhood or land of Huxley's birth, and those who may be desirous of assisting should communicate with the secretary to the fund, Mr. B. B. Woodward, 120 The Grove, Ealing, London, W.

A MEETING was held at Cambridge University on April 27 to arrange for some acknowledgment of the services to science and the University of Prof. G. D. Liveing. Professor Liveing is now seventy-three years of age. In 1852 he organized the chemical laboratory at Cambridge, which was the first scientific laboratory in the University.—Mr. Herbert Spencer celebrated his eighty-first birthday on April 27. Mr. Spencer lives quietly at Brighton. His health is fair, but he is unable to undertake much literary work.—A silver loving cup was presented by a number of teachers to Mr. Thomas Meehan, the veteran horticulturist and botanist, of Philadelphia, on the occasion of his seventy-fifth birthday.

DR. EDMUND ARTHUR ENGLE, professor of mathematics at Washington University, St. Louis, and dean of the College of Engineering, has been elected president of the Worcester Polytechnic Institute.—Mr. J. H. H. Teall has succeeded Sir Archibald Geikie as director-general of the British Geological Survey.

SEVERAL important scientific positions under the government will be filled by civil service examination on June 3. These include the positions of plant physiologist and plant pathologist in the Department of Agriculture, with salaries of $1,800 per annum, and the position of ethnologist in the Bureau of American Ethnology, with a salary of $1,500. Further particulars can be obtained by addressing the Civil Service Commission at Washington, D. C.

AT the last meeting of the Rumford Committee of the American Academy of Arts and Sciences a grant of $300 was awarded to Prof. Arthur A. Noyes in aid of a research on the effect of high temperatures upon the relative conductivity of aqueous salt solutions.—Dr. Edmund B. Wilson, professor of zoology at Columbia University, and Dr. J. Playfair McMurrich, professor of anatomy at the University of Michigan, are among the Americans who will attend the International Zoological Congress to be held in Berlin from the 12th to the 19th of August.

THE arrangements for the celebration of the bi-centennial of the Yale University in October next have now been made public. The addresses include one by President Gilman, of the Johns Hopkins University, on 'Yale in its Relation to Science and Letters,' and one by Prof. W. H. Welch, of the same University, on 'Yale in its Relation to Medicine.'

THE United States Department of Agriculture has established an agricultural experiment station in Porto Rico, which will be under the direction of Mr. Frank D. Gardner, now of the Division of Soils.